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INHERITANCE OF MAMMÆ IN DUROC JERSEY SWINE

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THE relative fixity of character and definite methods of variation in the mammæ of swine make them a fruitful field for inheritance studies. The observations incorporated into this paper were made upon swine used in a feeding experiment at the Iowa State College. There were fifty-seven grade Duroc Jersey sows and five hundred and ten pigs of 1912 farrowing included in the investigation.[1]

The sows may be divided into two groups, one of forty two-year-old animals and the other of their yearling daughters, seventeen in number. In all, there are three generations for comparative study, a rare combination in such numbers among ordinary slow-breeding farm animals. There were two boars in use in the experiment. one a yearling, the other a two-year-old, both closely related as ordinary pedigree breeding is considered. From the standpoint of mammæ pattern, the boars were

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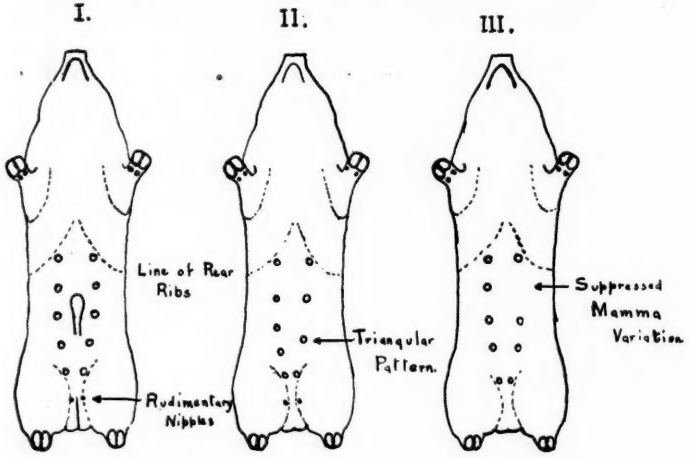
quite similar somatically, the only difference being that the asymmetry present occurred on opposite sides in the two animals. In the older boar the right nipple of the second pair was not developed, and in the younger boar the left nipple of the same pair was suppressed.



The Mammæ Pattern.—What may be termed the "normal" mammæ pattern consists in the occurrence along the ventral side of regularly placed pairs. The first pair lies just behind the junction of the ribs with the sternum. The last pair is inguinal in position, and its members lie close together near the median plane. The intermediate pairs are spaced about equally between, although a slightly greater distance separates the last two pairs. In the male with ten mammæ (five pairs), the sheath opening lies between the second and third pairs, while the fourth pair is about the same relative distance to the rear of the third. In the female the nipples are similarly placed, but less readily located in a definite manner, because of the absence of the sheath.

It has been assumed by some writers that the paired mammæ bear a relation to the metameric structure of the

individual. Williams particularly contends for this view, claiming that each somite in the original ancestral condition possessed its pair of glands. He also invokes the theory of reversion to account for the definite places in which supernumerary nipples occur. Bateson, on the contrary, defines the position of the teats as occurring regularly on the "mammary lines." These lines diverge toward the axillæ and converge toward the inguinal region. He assumes that mammæ may appear at any point on these lines and apparently with only slight relationship to the somites.

Embryology.—Embryologically, Bateson's idea of the mammary lines seems to be well supported. In the swine embryo of 14–15 mm. the mammary ridges appear plainly visible in a dorso-lateral position. At about 17 mm. small elevations ("primitive teats") appear on the surface of these ridges. When about 19–20 mm. long, the intervening parts of ridges are resorbed, leaving the teats at the point in which they will normally develop.

This entirely precedes the formation of the true mammary tissue. In fact Creighton says that in the kitten the latter may not appear until after birth, although guinea pigs and swine show an earlier development. The factors that govern the transverse division of the lateral mammary tissue into mammæ, so far as the writer has been able to discover, are unknown. Most authors have insisted that metamerism has nothing to do with it, but offer little demonstrable in its place. Suffice it to say, however, there is some force that serves to maintain symmetry and regularity of division in the majority of cases. An attempt will be made to show some of its effects in the following study, even though it can not be definitely named and its action described.

Types of Variation.—The simplest type of variation in the number of mammæ consists of one more or one less pair than is the usual number. The writer has assumed the first pair and the inguinal pair constant, because of their definite position. On this assumption, the addition

or substraction of a pair of mammæ must occur at some intermediate point. If a pair is added, it may be associated with a closer spacing of the teats, or possibly with a greater body length from the tip of the sternum to the border of the groin. If subtracted, the opposite condition would obtain. No observations were made on this point, and indeed it would be difficult to make them, because of the elastic nature of the tissue, the difficulty in handling the animals, and their marked variability in size and proportions.

There are two common sorts of asymmetry that may occur separately or together. These are the "suppressed nipple" and the "triangular" patterns. The former consists in the non-appearance of one member of a pair, while the latter shows one teat placed opposite two teats on the other side. The single teat is located at a point midway between the opposite two, and is always on the mammary line. The suppressed mamma variation appeared in 29.8 per cent. of the offspring and the triangle in 21.7 per cent.

The suppressed mamma variation may occur twice in the same animal, either on the same or opposite sides of the body, the two sorts of repetition being about equally frequent. But whenever the variation is repeated on the same side of the body, a normally placed pair of mammæ always intervenes. Less frequently a pair of mammæ seems to be omitted altogether, leaving an empty space where normally a pair of mammæ would occur. This may be interpreted as the suppression of two mammæ on opposite sides in one pair. The writer is rather doubtful of this interpretation, however, and does not include it in the 29.8 per cent. already mentioned. The omission of a pair was found in only 5 cases, or less than 1 per cent. of all.

The triangle pattern shows three or perhaps four types of compounding. Two triangles may appear with the single nipples on the same side and separated by one or more normal pairs, or they may be separated similarly,

but have the single nipples on opposite sides. The third type is where no normal pair divides the two triangles and two mammæ on one side balance three on the other. In this case, where more than two triangles are present, three nipples on one side may balance four opposite or four may balance five. This last condition occurred in only two cases. The fourth type is doubtful and difficult to describe. It is as though the two triangles have their bases on opposite sides of the animal, but have one side in juxtaposition with the corresponding side of the other. In other words, two of the mammæ form the sides of two oppositely facing triangles and give a two-balancing-two effect. The mammæ on one side are opposite a point intermediate between those on the other. This effect may possibly be brought about by a combination of the suppressed nipple and triangle type as well. In seven individuals the triangle and suppressed nipple were found on the same animal, separated by one or more normal pairs.

There sometimes appears a pattern in which the mammæ of one side are set ahead of the points where they commonly occur, as though one lateral row were pushed slightly forward. This may be characteristic of the entire mammary series or of only one or two pairs. The arrangement is seldom so distorted that the identity of the pairs is lost, but occasionally it approaches the fourth compound type of triangle just discussed. A suggestion has been offered that this distortion may be due to the position of the fetus during pregnancy, so that when the abdominal walls grow together, the mammæ do not lie exactly opposite. An objection to this is that not only would the abdomen show the asymmetry, but also the ribs and sides. No observations were made on this point, but to the writer the explanation offered seems doubtful.

The Seat of Greatest Variation.—For convenience in description, the pairs of mammæ may be numbered from the most forward pair to the rear. Considering the first pair and inguinal pair as constant, the mammæ of the intervening region were tabulated by number. This

method, of course, made the fifth and sixth pairs of much lower frequency than the other five, since so many animals had but ten mammæ. In figuring percentage frequencies for each position the total number of mammæ possible in all of the animals, if each had a pair in the position under consideration, was used as a basis for computation. The columns 1½, 2½, etc., show the frequencies of mammæ forming the apex of a triangle, in the position between pairs 1 and 2, 2 and 3, etc.

The total number of mammæ for each position which could occur if there were no variations is 1,138 for the first four and inguinal pairs. The constancy of the last named pair is particularly marked, only nine variations obtaining.

	Pair						
	1	1½	2	2½	3	3½	4
No. nipples	1,112	25	989	37	1,088	14	1,095
Per cent. frequency mammæ	97.715	2.2	86.906	3.25	95.606	1.23	96.221
Per cent. frequency variations	2.285		13.094		4.394		3.779

	Pair					
	4½	5	5½	6	6½	Inguinal
No. nipples	19	649	28	127	7	1,129
Per cent. frequency mammæ	2.7	92.187	16.09	72.987	4.023	99.209
Per cent. frequency variations		7.813		27.013		0.791

Arranging the pairs in order of frequency of variation, the following sequence holds: 6th, 2d, 5th, 3d, 4th, 1st and inguinal. It is probable that the rank of the sixth is not significant, due to the lack of numbers in proportion to the others, but there is no question about the second pair being a leading seat of variation. In a former article on this subject the writer called attention to this fact without presenting figures. It is worth while noting that this variance in the second pair is perhaps not characteristic of swine as a whole, but simply due to the fact that both boars showed in this pair their variation from normal patterns.

The point of most frequent appearance of the triangu-

lar type is of interest, although possibly not significant. The rank is as follows:

	Per Cent.
Between 5th and 6th	16.09
Between 6th and 7th	4.023
Between 2d and 3d	3.25
Between 4th and 5th	2.7
Between 1st and 2d	2.2
Between 3d and 4th	1.23

Once more, if we discard the results between 5th and 6th, and 6th and 7th, because of small numbers, we find the high per cent. of variability at the second pair.

The point of appearance of the suppressed nipple variation was plotted in the same way and the following order of appearance was found:

	Per Cent.
6th pair	6.9
2d pair	6.3
5th pair	1.3
4th pair	1.1
3d pair	0.5
Inguinal pair	0.2
1st pair	0.0

Again the second pair is shown as the chief seat of variation. It may be well to mention that while there was a possibility of 1,138 mammæ appearing in the 1st, 2d, 3d, 4th, and inguinal pairs, only 704 mammæ could have appeared in the 5th pair and 174 mammæ in the sixth, because of the small numbers of animals having over ten and twelve mammæ, respectively.

No. Triangles	5 Prs.	6 Prs.	7 Prs.	*f*
1	4	53	23	79
2		8	10	18
3		2	1	3
4			1	1
f	4	63	35	101

Mean No. triangles = 1.267.
Standard deviation triangles = .5609.
Mean No. pairs mammæ = 6.3168.
Standard deviation pairs = .7889.
$r = .1666 \mp .065$.

Relation of Increased Pairs to the Common Variations.—A correlation was arranged between an increased number of pairs and the two common asymmetrical variations.

No. Suppressed Nipples	5 Prs.	6 Prs.	7 Prs.	f
1	1	91	24	116
2			9	9
	1	91	33	125

Mean of suppressed nipples = 1.072.
Standard deviation of suppressed nipples = .258.
Mean No. pairs = 6.256.
Standard deviation = .408.
$r = .5089 \pm .0447$.

While the correlation does not show a marked relation between the number of triangles and the increased number of mammæ, yet another method of plotting shows that there is a very significant relation between them and that the tendency to these variations may possibly be only a function of a large number of mammæ rather than a definitely heritable unit.

	No. of Pairs		
	5 Prs.	6 Prs.	7 Prs.
No. animals	217	296	56
No. each kind of animals with triangle	4	63	35
Per cent. animals of each class with triangle	1.84	21.28	62.5
No. animals of each class with suppressed mammæ	1	91	33
Per cent. animals of each class with suppressed mammæ	.46	30.74	58.93

The increased percentage of animals with the two types of variation among the animals with a larger number of mammæ speaks for itself.

This relation of the variations to the increased number of pairs, in connection with the fact that the variations appear most frequently in the pairs between the first, and inguinal, furnishes additional basis for the statement made earlier in the paper that the number of mammæ is increased by modifications between the first and inguinal pair.

Inheritance of the Two Forms of Variation.—The "triangles" show a marked degree of inheritance. Neither boar carried the triangular pattern somatically, but the offspring of the two were summarized separately to see if any difference developed in the offspring. Both boars possessed the "suppressed nipple" type, and, as might be expected, show little difference in breeding.

PIGS BY OLD BOAR

		Pigs with Triangle	Pigs with Suppressed Nipple	With Neither
Sows with triangle.....	No.	17	11	28
	Per cent.	30.00	20.00	50.00
Sows with suppressed nipple...	No.	2	14	26
	Per cent.	4.7	33.3	62.0
Sows with neither.....	No.	45	60	169
	Per cent.	16.6	22.2	62.5

It is evident that a distinctly higher proportion of "triangles" appears in the pigs from sows of the same type. Also a distinctly greater percentage of pigs with the suppressed nipple comes from sows of the suppressed-nipple type, but the difference between the breeding character of the three classes of sows is not so marked with this variation, probably because the boar supplies the latter pattern with each mating.

PIGS BY YOUNG BOAR.

		Pigs with Triangle	Pigs with Suppressed Mamma	With Neither
Sows with triangle.....	No.	13	4	16
	Per cent.	39.394	12.121	48.485
Sows with symmetrical pairs...	No.	9	23	62
	Per cent.	9.574	24.468	65.957

Combining the two tables, there appears a result which may be more significant than in either when separate. In this table in the cases where a pig possesses both variations, he is listed twice, so that the percentage runs slightly over one hundred. There is one duplication from sows with the triangle and four duplications in the offspring of the "normal" sows.

		Pigs with Triangle	Pigs with Suppressed Mamma	With Neither
Sows with triangle.....	No.	30	15	44
	Per cent.	34.091	17.045	50.000
Sows with suppressed mamma .	No.	2	14	26
	Per cent.	4.762	33.33	61.905
Sows with even pair.....	No.	54	83	231
	Per cent.	14.835	22.802	63.461

It is of interest to note that each form of variation appears in about one third of the offspring of the mothers that bear the same variation. Where the mother does not possess either type, the triangle appears in about one-seventh of the offspring and the suppressed mamma in one fourth. It is possible that a three-factor Mendelian ratio would account for the results, but since the factors are unknown it is scarcely worth while to present it.

Two of the sows possessed both the triangle and the suppressed mamma, and are not listed above. A close agreement with the preceding table may be noted.

		Pigs with		
		Triangle	Suppressed Mamma	Even Pairs
Sows with both variations.....	No.	15	1	10
	Per cent.	31.25	6.25	62.5

The constancy of the per cent. of even pairs in the two tables is undoubtedly worthy of notice. Neither boar possessed the triangle. Sows with the triangle produced 39 pigs with the triangle and 69 without. Sows without the triangle produced 56 pigs with it and 349 without. The character is apparently inherited as a distinct entity even though it may be merely a function of an increased number of mammæ. The sows without the triangle may be divided on their breeding performance into two groups. The first produced only offspring without triangles (124 pigs) while the second produced 56 pigs with triangles, 225 without. The proportions here look significant. In the first group the ratio of those possessing triangles to those without is about 1:2. In the second it is $O:N$ and

in the third 1:4. The relative frequencies of these three groups also look promising: 124 (*O*:*N*):281 (1:4): 108 (1:2). The simple 1:2:1 ratio is approximated, although the excess of the second group is a little high. Records on next year's pigs are needed to prove the soundness of this method of division.

In a similar way the suppressed mammæ show a strong degree of inheritance. Both boars possessed the suppressed mamma pattern. Sows with the suppressed mamma produced 17 offspring with it and 49 without. Sows without it produced 94 with and 350 without. The ratios are approximately 1:3 and 1:3.7. Separating the sows without the character into two groups on the same basis as in the preceding case the following appears: 65 (1:3) from sows with the suppressed mamma, 388 (1:3) from sows without the suppressed mamma and 56 (*O*:*N*) from sows without the suppressed mamma. The frequencies look like two 3:1 ratios combined in which the two groups of three and one group of one are similar, but it is not the normal ratio of 7:1. This also may be only apparent, however, and another year's test is needed to throw more light on the subject. It is beyond doubt, nevertheless, that these two forms of variation are distinctly inherited and the manner of inheritance only is that which remains to be demonstrated.

Evidences of Segregation of the Two Types of Variation.—The grand-dams were plotted against their pigs of the 1912 litters and the correlations were figured in comparison with the dams. The results were not enlightening, as the following table shows.

Correlation between No. triangles in grand-dams and 1912 pigs	$-.0064 \pm .0624$
Correlation between No. triangles in dams and 1912 pigs	$.2241 \pm .0592$
Correlation between No. suppressed nipples in grand-dams and 1912 pigs	$-.0966 \pm .0618$
Correlation between No. suppressed nipples in dams and 1912 pigs	$-.0052 \pm .0624$

In the negative correlations the probable error is either

approximately equal to the coefficient or else far larger, so that no emphasis can be placed on the result. In arranging them according to per cent. of offspring bearing the same variation the following is obtained:

	Per Cent. of Pigs with Supressed Nippie
Grand-dams without suppressed nipple	23.00
Dams without suppressed nipple	22.22
Grand-dams with suppressed nipple	11.76
Dams with suppressed nipple	11.11

No difference shows between the two classes, so it is possible that the presence of the variation in the boars tends to even things up.

	Per Cent. Pigs with Triangle
Grand-dams without triangle	15.31
Dams without triangle	10.47
Grand-dams with triangle	16.66
Dams with triangle	29.03

In the case of the triangle, the grand-dams without the variation have a higher per cent. of offspring possessing it than do the dams, but where the triangle is present in the dams and grand-dams the younger generation seems to have the greater power of transmission. Since the old boar previously mentioned is the sire of the dams, and the young boar the sire of the 1912 pigs, there has been no point of entrance for the triangle somatically. The percentages show some sort of segregation of a recessive character, but further matings are necessary to clarify the matter.

Variation in Number of Mammæ.—There is quite a wide range in the number of teats that may be present. The smallest number found in these litters is nine, while in the litters of last year, elsewhere reported, one pig appeared with only eight. The highest number recorded on one animal was sixteen, these including a pair of rudimentaries to the rear of the inguinal pair. Of the mammæ on the mammary lines of the abdomen fourteen is highest number.

The relative frequency of occurrence of these different

numbers among the swine studied is shown in the following table:

	Number Mammæ					
	9	10	11	12	13	14
Number pigs	4	195	135	127	33	15
Per cent. frequency	0.78	38.31	26.52	24.95	6.48	2.95

Nearly 90 per cent (89.8) of the pigs bear ten, eleven or twelve mammæ, and may therefore be considered the normal types of the Duroc Jersey. In Bateson's data on Tamworth's and cross-bred Berkshires in his "Materials for the Study of Variation," he finds that twelve is the lowest number of mammæ occurring, fourteen is the mode and seventy-seven per cent. fall on thirteen, fourteen and fifteen. His numbers are much smaller (35), but it is highly probable that there is a difference in breeds as regards number of mammæ, particularly between those of bacon and lard type.

Correlation of Number of Mammæ between Dams and Pigs.—The coefficient of correlation for number of mammæ between the sows and pigs was not high ($.2626 \pm .028$), yet it showed distinct inheritance. There was apparently no difference due to sex, as the boar pigs showed a correlation of $.1734 \pm .04$ to their mothers, and the sow pigs were only slightly greater, $.2133 \pm .04$. Since with the probable errors in consideration the two coefficients overlap, it seems doubtful if sex makes any difference in the inheritance.

Evidence of Segregation in Number of Mammæ.—The sows of the first generation were plotted against their grand-daughters giving the following results.

Grand-dams	Number of Mammæ of Pigs						
	9	10	11	12	13	14	Total
10		8	4	1			13
11	1	5	4				10
12		39	25	4			78
13		7	5	1			13
14		1			1	1	3
Total	1	60	38	16	1	1	117

Coefficient of correlation $= .2962 \pm .057$.

The parents themselves showed a correlation to the offspring as follows:

Dams	No. Mammæ Pigs						
	9	10	11	12	13	14	Total
10	1	29	12	10			52
11		5	6				11
12		21	18	6			45
13		1			1	1	3
14		4	2				6
Total.....	1	60	38	16	1	1	117

Coefficient of correlation $= .1418 \pm .061$.

The grandparents are much more closely correlated with the pigs ($.2962 \pm .057$). Two explanations may be offered for this. Among the fifteen dams there were five pairs of sisters, so that there were only ten grand-dams to correlate. This would throw some of the litters into one class that were separated when correlated with the dams and so would modify the coefficient. An interpretation more satisfactory to the writer is that the higher coefficient between grand-dam and offspring represents the segregation of some mammary character the limits of which can not, at present, be defined.

Relation of Asymmetrical to Symmetrical Pattern.—An interesting point because of the constancy of the ratio lies in the relation of the symmetrical and asymmetrical patterns. In the pigs they occur in the ratio of 1:2, or 172 asymmetrical to 337 symmetrical. In the writer's paper of last year, already cited, the same ratio held and seemed unaffected by patterns in the parent. If divided according to sex, we find no difference, the boars showing 89 asymmetrical to 174 symmetrical and the sows showing 83 of the first to 163 of the second. The fact that both parents bear the asymmetrical pattern may influence the per cent. of asymmetry in the pigs, but this influence is very slight. Where boar and sows were asymmetrical the ratio was 50:85, while when the boar only was asymmetrical the ratio was 122:252. Putting them on the same

basis, we find a ratio of 1:1.7 and 1:2.06. There may be significance in the difference between the two ratios, but the writer is inclined to think there is not, for last year's work gave 35 asymmetrical to 68 symmetrical pigs from two asymmetrical parents, and 33 to 62 from one asymmetrical parent.

Another method of plotting these ratios shows that differences may occur in connection with an increased number of pairs. When the animals have ten pairs, only four animals out of 199, or less than two per cent., show the variations. When the animals have six pairs, the number of animals having even pairs throughout are about equal with the number having the variation, 127 and 135, respectively. When the animals have seven pairs, the chances are about two to one that the animal will have one or the other variation (33:15). Placed on a percentage basis the following table results, showing that asymmetry is closely related to an increased number of pairs.

	Animals with		
	5 Prs.	6 Prs.	7 Prs.
No. animals	199	262	48
No. animals with the variations	4	135	33
Per cent. animals with the variations	2.01	51.52	68.75

Inheritance of Asymmetry.—The old boar possessed his asymmetrical nipple on the left side, the young boar on the right. The two boars were tabulated in their matings to sows possessed of each kind of asymmetry.

OLD BOAR (EXTRA NIPPLE ON LEFT)

	Pigs with Extra Nipples On Left	On Right
Sows with extra nipple on left	18	16
Sows with extra nipple on right	4	6
Symmetrical sows	45	47

YOUNG BOAR (EXTRA NIPPLE ON RIGHT)

	Pigs with Extra Nipples On Left	On Right
Sows with extra nipple on left	3	9
Sows with extra nipple on right	0	1
Symmetrical sows	11	25

With the older boar no evidence of the inheritance of unilateral asymmetry is shown. With the younger boar, however, there is a distinct excess of pigs showing the asymmetry on the same side as the father. Since there is no means of telling from the external appearance what recessive characters the sow may be carrying, it is possible that there is a marked difference in the lateral predisposition of the two boars.

An examination of the offspring of asymmetrical and symmetrical sows shows a slight tendency toward the production of asymmetry in the offspring of that kind of parents. Eighteen sows of this type produced 96 pigs with even pairs and 74 without. Thirty-nine symmetrical sows produced 215 pigs with even pairs and 125 without. Using the asymmetrical pigs as the base, the first ratio is 1:1.297 and the second is 1:1.72. While we are justified in assuming a degree of inheritance of asymmetry, we are not yet able to show the same by definite units.

Is Inheritance Lateral or by Pairs?—The embryological origin of the mammary tissue suggests that there may be a lateral inheritance. In order to determine this, the right side of the mother was correlated with both the right and left sides of the offspring, and the left side of the mother correlated in the same way. The offspring of the two boars were separated, since the old boar had six teats on the left side and five on the right, while in the young boar this relation was reversed.

The results were disappointing if one expected a high correlation.

	Pigs by Young Boar	Pigs by Old Boar
Right side dam to right side pig	.1196 ± .0353	.1601 ± .0346
Right side dam to left side pig	.0384 ± .0353	.2326 ± .0346
Left side dam to right side pig	—.0023 ± .0353	.1436 ± .0346
Left side dam to left side pig	—.0296 ± .0353	.2132 ± .0346

In the last three correlations in the pigs by the young boar, the probable error equals or exceeds the correlation, and in the pigs by the old boar, the probable error permits the correlations to just about meet each other or

even overlap. In the pigs by the young boar the correlation between the same sides of sow and offspring exceeds that of the opposite sides, but in the offspring of the old boar the left side of the pig is more closely correlated to either side of the mother than is the right side of the pig. These contradictions lead the writer to believe that the inheritance is not lateral.

All of the offspring were tabulated as to number of pairs against their dams and the correlation was determined. The coefficient is $.1994 \pm .028$, large enough to show some inheritance. As the animals included here possess the two common types of variation, or were from dams possessing those types, a second table was prepared of pigs with symmetrical pairs from sows of the same type. A larger coefficient resulted, $.3588 \pm .039$, but even this is not satisfactory, as the boars possess the suppressed nipple, and of course, the offspring represent a selected group, although not selected from a standpoint that should favor the correlation.

Another method of tabulating may show the inheritance more graphically. The boars have six pairs, with one mamma suppressed.

No. Pairs in Sow	Av. for Offspring All Individuals	Av. for Symmetrical Individuals
5	5.57	5.27
6	5.76	5.48
7	5.90	5.65

There is a distinct increase in the means of the offspring as the number of pairs increases in the parent. The mating of the boars to the sows with the following number of mammæ is interesting:

Boars	Sows	Pigs with 5 Prs.	6 Prs.	7 Prs.
6 prs.	5 prs.	69	60	2
6 prs.	6 prs.	103	162	34
6 prs.	7 prs.	28	40	12

This corroborates the results above.

The foregoing tables lead the writer to believe that the method of inheritance is by the pair rather than the side,

although the determination of the pair as a Mendelizing unit must be deferred until further study is made.

Rudimentaries in the Abdominal Series.—Bateson looks on rudimentaries that occur asymmetrically in the abdominal series of mammæ, as a sort of supernumerary organ systematically and different qualitatively from the normal mammæ. He so classifies them because of their visible differences and because of their ability to displace normal mammæ from the ordinary paired state. It seems to the writer that while this distinction may be all right from Bateson's standpoint, from the standpoint of heredity it is without weight. The factor that causes the transverse sectioning of the strips of mammary tissue is obviously separate from the forces that cause development of the glands. This factor operates irrespective of whether the gland be destined to develop or not, and it is very evidently this factor (probably complex) that is inherited.

At birth or shortly after it is difficult to tell whether a mamma will develop functionally or not. There are some that are so small and undeveloped that one may be positive as to their rudimentary state throughout life, but there are others for which prediction is very uncertain. The writer has left all doubtful cases out of consideration and has figured asymmetry due to a rudimentary nipple in relation to asymmetry produced by developed teats.

There are 89 asymmetrical males. One of these is asymmetrical from the presence of a rudimentary; two more possess a rudimentary each, but are asymmetrical through the presence of functional "triangles"; and two symmetrical boars possess rudimentaries as one member of a pair. It must be understood in connection with the foregoing that all of the mammæ of the male are really rudimentary, and that what the writer has termed rudimentary in the preceding statement refers to mammæ that are so much smaller as to occupy a relation similar to the rudimentary and normal mammæ in the young female.

Eighty-three asymmetrical sows show only one individual whose asymmetry is due to the presence of a rudimentary. One sow has a rudimentary, but is asymmetrical from a functional "triangle," and one symmetrical sow shows a rudimentary in one of her pairs.

Summarized this shows that only 1.123 per cent. of the asymmetrical males have their asymmetry caused by rudimentaries, and only 1.204 per cent. of the females. From this evidence it would seem that rudimentaries do not represent a step in the variation of the mammary linear series, but from the standpoint of heredity should be treated the same as normal teats, the lack of development being probably due to fluctuating somatic causes.

It is interesting to compare the variability of the nipples of the male, which are rudimentary throughout life, with the teats of the female, which are potentially functional. The coefficient of variability for the boar pigs is $.1009 \pm .003$ and for the sow pigs it is $.0943 \pm .0028$. The probable error permits a minimum separation of the two coefficients of only .0008, so that the difference between the two is probably not significant. In the litters of 1911, already referred to, the boar pigs were slightly more stable than the sows, which would further argue against a qualitatively constant significant difference.

The Rudimentaries to the Rear of the Inguinal Pair.— In the previous discussion no account has been taken of a pair of rudimentaries which occur on the lower forward part of the scrotum of the male, and well to the rear on the inner thighs of the female. The pair is entirely distinct from the others, and readily recognizable from its location and also from the fact that so far as the writer has observed it is always rudimentary. It seems probable that it lacks almost entirely the backing of mammary tissue found in the other mammæ. The writer has already described the inheritance of the character in another paper, so will simply summarize the results. The pair behave as a Mendelian unit character in heredity, dominant in males but recessive in females. That is, it is

developed somatically in the male when either simplex (*Rr*) or duplex (*RR*), but develops in the female only in the duplex (*RR*) condition. The boars used were simplex from their behavior in breeding, while the sows embodied all three types.

BOAR (*Rr*)

Low Type	No. Sows		Boar Pigs		Sow Pigs	
			Absent	Present	Absent	Present
RR	9	Expectation	0	39	20	20
		Actual	0	39	27	13
		Expectation	17	51	66	22
Rr	16	Actual	23	44	64	24
		Expectation	60	60	95	0
rr	24	Actual	66	54	95	0

Fifteen of those recorded in the first two columns were daughters of some of the remaining. In each case the gametic composition assigned the young sows from their breeding performance confirmed the formula assigned the mother. There is some variation from the expectation particularly in the female pigs from the *RR* sows and the male pigs from the *Rr* mothers. The numbers are too small to permit of the deviation being significant, however, and the departure from expectation in the sow pigs in the first instance shows that the rudimentaries are not a distinctly feminine character. Attention should be called to the fact that in the male the deviations from expectation are on the same side.

The following table was plotted to see if the rudimentaries are a function of an increased number of mammæ, similar to the two common types of variation.

	Number of Mammæ per Animal					
	9	10	11	12	13	14
No. animals	4	181	131	135	36	16
No. animals with rudimentaries	3	59	58	52	10	1
Per cent. latter	75.00	32.59	44.28	38.52	27.77	6.25

The fluctuating percentages in connection with the fact that the two lowest percentages are recorded against the

highest numbers of mammæ, would incline the writer to believe that the rudimentary mammæ of the scrotum and thigh are independent of the abdominal series, and furthermore that the Mendelian interpretation is correct.

Conclusions.—I. There are two common sorts of variation from the even paired type in the mammæ of swine, aside from the simple addition and subtraction of pairs. These are the "triangle" and "suppressed" nipple variations. Each shows a definite tendency to reproduce itself in the offspring, but both are apparently associated with an increased number of pairs.

II. The seat of the greatest variation in the animals under discussion is the second pair of mammæ. This is perhaps due to the type of variation in the sires.

III. There is apparently a breed difference in regard to the number of mammæ. Bateson shows that in Tamworths and Berkshires, 13, 14 and 15 mammæ are typical, occurring in 77 per cent. of the cases. The Duroc Jerseys studied show in 90 per cent. of the animals, 10, 11 or 12 mammæ.

IV. The ratio of asymmetrical to symmetrical patterns increases as the number of mammæ increase. With five pairs symmetry is almost constant; with six pairs, symmetry and asymmetry are equal. With seven pairs asymmetry outnumbers symmetry 2 to 1.

V. No evidence definitely showed that asymmetry is unilateral in inheritance. Asymmetry on one side of the parent does not, on the average, produce asymmetry on the same side only of the offspring.

VI. Sows differing in number of mammæ, when mated with the same boar, produce offspring variable in number of mammæ. In general, sows with a large number of mammæ produce more offspring of a corresponding sort than do sows with a small number of mammæ. The difference, however, is not great, and neither sort apparently breeds true. The correlation of mother and offspring in number of mammæ is measured by the coefficient $.2626 \pm .028$.

VII. There is a distinct inheritance of the tendency to produce a greater number of pairs, the correlation being $.3588 \pm .034$.

VIII. There is no evidence of lateral inheritance of the mammæ, the inheritance by pairs being a more probable hypothesis.

IX. No definitely Mendelizing units were found in the abdominal mammary series, but the relations between grandparents and offspring and parents and offspring, do indicate a segregation of some sort.

X. Rudimentaries in the functional mammary series have the same effect on the pattern as normal mammæ, and probably represent lack of development. There is no greater tendency to variation among the rudimentary nipples of the male than among the potentially functional nipples of the female.

XI. The paired rudimentaries to the rear of the inguinal pair behave as a simple Mendelian unit-character, sex-limited in inheritance.

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STUDIES OF NATURAL AND ARTIFICIAL PARTHENOGENESIS IN THE GENUS NICOTIANA.[1]

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PARTHENOGENESIS is a phenomenon that is known to exist in many widely separated genera of the higher plants. In but few cases does it seem likely that the regular reduction of gametogenesis with the subsequent nuclear fusion of fertilization never occurs, yet it is probable—from the frequent discovery of new examples—that it will ultimately be found that the ability to dispense with typical sexual reproduction is comparatively common. Should this prove to be the case, one would be forced to conclude that sexual reproduction was developed for reasons other than protoplasmic necessity, as Maupas and his followers would have biologists believe.

This is the fundamental problem toward the solution of which all data on parthenogenesis contribute, but pending the time when it can be discussed intelligently, there are sub-questions that are not without their interest. Loeb's researches have shown that the stimulus to development which is an attendant result of fertilization, is physico-chemical. Observations on several genera of parthenogenetic insects have shown that the presence or absence of sexual reproduction is largely dependent upon external conditions such as food, light, temperature, etc. Little is known of the rôle played by such stimuli in parthenogenesis in plants, however, although knowledge on the subject is of some import aside

[1] Contribution from the Laboratory of Genetics, Bussey Institution of Harvard University.

from theory. For example, the geneticist is concerned, if, under any of the conditions likely to obtain in his experiments, plants ordinarily reproducing sexually should be incited to reproduce parthenogenetically.

This paper describes some facts on the subject obtained by experiments on the genus *Nicotiana*.

THE MATERIAL.

The material used in the investigation was turned over to me by Professor E. M. East, who had received it from various parts of the world. Each species had been cultivated in pure lines for at least three generations, so that it may be considered to be fairly well known. The specific names used are those accepted by Comes in his "Monographie du genre Nicotiana," Naples, 1899. To his descriptions, and to such figures as are published in the *Botanical Magazine*, the plants corresponded perfectly. To all intents and purposes, therefore, the plants may be considered wild, although they have been under cultivation several years.

The writer desires to express his thanks to Professor East, under whose direction the investigation was carried out, for the use of the pedigreed material and for much valuable advice. Certain unpublished data obtained in his own researches on *Nicotiana* are incorporated with his consent.

HISTORICAL.

For historical purposes it is only necessary to give a brief review of Hans Winkler's paper, "Über Parthenogenesis und Apogamie im Pflanzenreiche," published in 1908; and the less comprehensive paper, "Parthénogénèse des Végétaux Supérieurs," of L. Blaringhem, published in 1909. Blaringhem in his historical account of this subject, states:

> Déja Camerarius dans sa lettre célèbre sur le sexe des plantes (*De sexu plantarum epistola*, 1694) reconnaît que dans ses essais de castration du Maïs il obtient, malgré l'absence de pollen, le développement de graines fertiles sur les épis latéreaux femelles.

Among the early observers of parthenogenetic[2] qualities in plants are given Spallanzani (1767–1779), Henschel (1817–1818), Lecoq (1827), Girou de Buzareinques (1827–1833), Ramisch (1833–1838), Bernhardi (1834–1839), Tenore (1854), Gasparini (1846) and Naudin (1856). As a few of the plants cited by these authors are at the present time the object of research, Blaringhem gives a list of the observed plants with an indication of the more doubtful.

The list is given as follows:

(*a*) Plantes Dioiques.

Bryonia dioïca d'après Naudin (confirmé en 1904 par Bitter),

Cannabis sativa d'après Camerarius, Spallanzani, Henschel, Girou de Buzareinques, Berhardi et Naudin,

Datisca cannabina d'après Wenderoth et Fresenius (très douteux),

Lychnis dioïca d'après Henschel et Girou de Buzareinques,

Mercurialis annua d'après Lecoq, Ramisch, Naudin et Thuret,

Pistacia narbonensis d'après Bocconi et Tenore,

Spinacia oleracea d'après Spallanzani, Lecoq et Girou de Buzareinques.

(*b*) Plantes Monoiques.

Cucurbita Melopepo, C. Citrullus et autres espèces d'après Spallanzani, Sageret et Henschel,

Ficus Carica d'après Gasparini,

Urtica pilulifera d'après Henschel (très douteux).

Winkler, in his introduction, cites *Cælebogyne ilicifolia* J. Smith, a diœcius member of the Euphorbiaceæ native to eastern Australia, which had been cultivated since 1829 at Kew in three "weiblichen Stocken," as the first mentioned case of seed production without the assistance of pollen grains. This observation led Smith to believe

[2] No doubt many of these observations were incorrect, owing to imperfect control.

that pollen is not essential for the perfecting of Euphorbiaceæ seed. In 1857 A. Braun described *Chara crinita* Wallr. as a true case of parthenogenesis. In 1877, Strasburger with the aid of modern technique found that the embryos in *Cælebogyne ilicifolia* were formed without fertilization, but that parthenogenesis was absent, as the embryos came not from unfertilized eggs, but from adventitious growths (Sprossungen) of the nucellus tissue. In 1900, Juel definitely proved its existence in *Antennaria,* thus establishing its presence in the higher plants.

As botanical investigators do not always agree in the use of the terms parthenogenesis and apogamy, Winkler divides all reproductive phenomena into three divisions, namely: Amphimixis, Pseudomixis, and Apomixis.

1. Amphimixis, which designates the normal sexual process.

2. Pseudomixis, which means the replacement of true sex-cell fusions by a false sexual process. Pseudomixis thus differs from amphimixis, essentially, only in the circumstance that the fusing cells are not differentiated as gametes. As an example of the pseudomictic (pseudomiktische) method of reproduction is cited *Lastrea pseudomas* var. *polydactyla* Wills, in which the sporophyte arises from a prothallium cell, its primordial nucleus fusing with a nucleus from a neighboring cell. Farmer and Digby (1907, p. 191) name this procedure "pseudoapogamy." All non-sexual nuclear or cell fusions must not be considered as pseudosexual, however, for there is an asexual cell fusion in addition to the sexual and the pseudosexual, as, for example, the nucleus fusion described by Nemec (1902, 1903) in chloralized roots of *Vicia,* and also the frequently mentioned nucleus fusion in the young ascus of the Ascomycetes.

3. Apomixis, which is the replacement of sexual reproduction by another, an asexual process, which is not bound up with nuclear fusions. For it, there is already another term, namely that of apogamy. This latter term was applied by de Bary (1878, p. 479) for the fact, "dass

einer Species (oder Varietät) die sexuelle Zeugung verloren geht und durch einen anderen Reproduktionsprocess ersetzt wird." The word apogamy used with the meaning intended by de Bary covers the term apomixis of Winkler; but as all the recent authors use the expression apogamy in a new sense, the introduction of a new term seems justifiable.

Apomixis is subdivided into vegetative propagation, apogamy, and parthenogenesis:

(*A*) Vegetative propagation consists of the replacement of fertilization by vegetative formations (Ausläuferbildungen), arising of leafy (blattbürtiger) shoots, vivipary and similar examples of simple vegetative division and the adventitious embryo formation from nucellus cells.

(*B*) Apogamy, the origin through apomixis of a sporophyte out of vegetative cells of the gametophyte, is subdivided into (*a*) somatic apogamy, if the cell or the cell complex which produces the sporophyte possesses the diploid chromosome number, and (*b*) generative apogamy, if the mother cells of the sporophyte carry only the haploid chromosome number.

(*C*) Parthenogenesis, the apomictic origin of a sporophyte from an egg, is subdivided into (*a*) somatic parthenogenesis, if the egg possesses a nucleus with the diploid or unreduced chromosome number, and (*b*) generative parthenogenesis, if the nucleus of the egg is provided with only the haploid number of chromosomes.

Winkler remarks, it is probable that the relations between somatic apogamy and apospory are very close, as the former without the latter is surely not thinkable, while the latter (the primary proceeding) may exist without somatic apogamy. Examples of somatic apogamy are given, but no certain cases of generative apogamy are known; nevertheless, Winkler is very certain that their existence is possible.

Somatic parthenogenesis can be obtained in two ways: first, it can combine with apospory, that is, a normal

sporophyte cell with the diploid number of chromosomes can grow directly into the gametophyte; second, the gametophyte can arise from the spores in the usual manner, except that the reduction division is discontinued. Examples are known for both cases. After discussing the cell division of the more interesting cases of somatic parthenogenesis, he sums up the families in which it occurs, as follows:

1. Polypodiaceæ (*Athyrium Filix-fœmina* var. *clarissima* Bolton and var. *unco-glomeratum* Stansfield; *Scolopendrium vulgare* var. *crispum Drummondæ*).
2. Marsiliaceæ (*Marsilia Drummondii* R. Br.).
3. Ranunculaceæ (*Thalictrum purpurascens, Th. Fendleri*).
4. Rosaceæ (*Alchimilla* § *Eualchimilla*).
5. Thymelæaceæ (*Wikstroemia indica*).
6. Compositæ (*Antennaria alpina, A. fallax, A. neodioica; Taraxacum; Hieracium* § *Archieracium* and § *Pilosella*, almost completely).

According to Juel (1900, 1904), Murbeck (1901), Guérin (1904) and Strasburger (1904, 1907), somatic parthenogenesis is simply a vegetative process, the egg being merely an ovate-shaped body cell of the sporophyte. Winkler disagrees with this opinion, for if it be true, the female individuals of parthenogenetic plants could produce only female offspring. But this is not the case, for from parthenogenetic seed of *Thalictrum Fendleri,* Day obtained seeds which yielded abundantly staminate and pistillate plants. Thus, it is conclusively proven that cells are not always equivalent, even though they are physiologically and morphologically alike.

Two theoretical cases of generative parthenogenesis are given as thinkable; first, the whole cycle of development could occur without a change in the number of chromosomes, that is, the haploid number is retained throughout; second, a regenerative doubling of the chromosomes could appear in the development of an egg with the haploid number into the sporophyte. No examples of the latter are known to occur in the plant kingdom.

Merogany (Merogonie) is given a brief notice. This expression was first used by Delage (1899), for the successful fertilization of a denucleated fragment of an egg by a spermatozoon. It was established in animals by O. and R. Hertwig (1887) and Boveri (1889) and in the plant *Cystosira barbata* by Winkler (1901).

Parthenocarpy is more fully discussed, as it has much in common with both parthenogenesis and apogamy, and is a great source of danger in investigations made to determine their presence or absence. Noll (1902) introduced the term, and defined it as the capacity of many plants, under exclusion of pollen, to form fruits outwardly normal, but in which seeds are absent or aborted. This condition was discovered by the elder Gärtner (1788) who named it "*frutificatio spuria*" and was for the first time critically investigated by the younger Gärtner (1844), who called it "Fruchtungsvermögen." Winkler thinks that it might be possible to separate the cases of stimulative parthenocarpy, in which the seedless fruits are produced only after pollination with their own or foreign pollen or in consequence of an insect prick or some other irritation; and the cases of vegetative parthenocarpy, in which the seedless fruits are formed without any pollination or other outer irritation. The latter phenomenon is thought to occur less frequently than the former. Noll in 1902 described it in the cucumber (Gurke) and mentioned the then known cases, the fig and the seedless medlar. Ewert[3] has found that several kinds of fruit can develop without the assistance of pollen. The best results were obtained when all the blossoms of an individual plant were protected from fertilization, as otherwise the fertilized flowers were so markedly favored in their development when compared with the remaining unfertilized ones, that the latter dropped while immature.

[3] Ewert (1909, 1911) has noted the presence of parthenocarpy in the apple, pear, grape and gooseberry, and Kirschner (1900) has noted the same in the quince.

The relation between parthenocarpy and parthenogenesis of higher plants is very close, as all the known cases of parthenogenesis are associated with parthenocarpy, for not only embryos and seeds, but fruits develop at the same time without fertilization. Since both fruits and seeds which appear perfectly normal will develop, although they are without embryos, one can not be positive about parthenogenesis unless the presence of the embryo is ascertained.

In the discussion on the causes of parthenogenesis and apogamy, Winkler suggests the possibility of physico-chemical changes operating in a flower in consequence of non-pollination, and causing the parthenogenetic development of the ovules. Also, similar changes might be induced by the entrance of the pollen tube, even though fertilization did not take place, as when parthenocarpic fruits appear. If mutations occur which can supply the proper conditions for these physico-chemical changes, then it is possible to explain the inheritance of the parthenogenetic character after it has once appeared. Physical changes in the cytoplasm surrounding the egg, as well as changes in the osmotic pressure, are considered as only theoretical explanations for parthenogenesis. If they should be a cause, Winkler asks, why should these changes occur in some flowers and not in others; and if they appear in all flowers, why should not parthenogenetic embryo formations occur in all?

One who is not acquainted with Winkler's and Blaringhem's papers should refer to the originals, as it is impossible to give all the subject matter proper treatment in a brief review. The complete bibliographies appended to these papers are also well worthy of reference.

TESTS FOR THE PRESENCE OF NATURAL PARTHENOGENESIS IN THE GENUS NICOTIANA

The writer obtained no viable seed in his numerous castration experiments with the exception of one doubt-

ful case of *N. plumbaginifolia.* The seed of this exception was secured in a field experiment conducted on the heavy clay loam of western New York, used as a check on the experiments of Professor East made on the light sandy loam of eastern Massachusetts. Since the seed from this one capsule of *N. plumbaginifolia* was all that was obtained from ninety-eight emasculated blossoms of this species, it is reasonable to treat it as the result of an experimental error.

The method of testing for parthenogenesis in these field experiments consisted simply in emasculating and covering the flowers. Both paper sacks and cotton batting were used to protect the stigmas from self or cross-pollination. When the latter covering was used the anthers were removed with the assistance of a small wire hook which minimized the injury to the corolla and the cotton wad was then fastened over the end of the corolla tube with the aid of a rubber band. The supposed advantage of the cotton batting was that it would interfere less with the photosynthesis processes, than the paper sack, as it excludes much less air and sunlight. The seed of *N. plumbaginifolia* was obtained from a capsule covered with the cotton batting; otherwise, no definite results were noted in favor of either covering. As the heavy rains and strong winds will break off the capsules covered with cotton, it is advisable to enclose them with netting sacks.

The extent of these emasculation experiments of Professor East and myself in which not a single seed was produced outside of the capsule of *N. plumbaginifolia* already noted, is already seen by referring to Table I.

Mrs. R. H. Thomas was much more fortunate in her emasculation work, as she obtained fertile seed with no apparent difficulty. Why parthenogenetic tobacco seed should develop so readily in England and so rarely, if ever, in the eastern part of the United States is difficult to understand. The explanation may be found in the differences of the soils and the climatic conditions of the

two places, but this assumption is improbable. It seems more likely that new buds which escaped notice were developed in the course of her experiments. This explanation of these divergent results is very probable, as adventitious buds appear for several weeks after the formation of the first buds. Both self-fertilized and parthenogenetic blossoms produce offspring true to the mother species; and consequently an error, if it did occur, could not be detected.

TABLE I

FIELD CASTRATION EXPERIMENT

Species	Mass.			N. Y.		
	No. Buds	Treatment	No. Seed	No. Buds	Treatment	No. Seed
N. alata var. *grandiflora*	14	Emas. and covered	0		Emas. and covered	
N. attenuata				17	Emas. and covered	0
N. Bigelovii	12	Emas. and covered	0			
N. Forgetiana	20	Emas. and covered	0			
N. glutinosa	8	Emas. and covered	0			
N. Langsdorffii	12	Emas. and covered	0	54	Emas. and covered	0
N. Langsdorffii var. *grandiflora*	8	Emas. and covered	0	87	Emas. and covered	0
N. longiflora	16	Emas. and covered	0	45	Emas. and covered	0
N. paniculata	21	Emas. and covered	0			
N. plumbaginifolia	11	Emas. and covered	0	98	Emas. and covered	Several (1 capsule)
N. quadrivalvis	14	Emas. and covered	0			
N. rustica var. *brazilica*	14	Emas. and covered	0	16	Emas. and covered	0
N. rustica var. *humilis*	20	Emas. and covered	0	113	Emas. and covered	0
N. rustica var. *texana*	12	Emas. and covered	0			
N. suaveolens	10	Emas. and covered	0	13	Emas. and covered	0
N. tabacum (broadleaf)	10	Emas. and covered	0	11	Emas. and covered	0
N. tabacum (calyciflora)				83	Emas. and covered	0
N. tabacum (fasciated)	14	Emas. and covered	0			
N. tabacum (Havana)	28	Emas. and covered	0			
N. tabacum (Sumatra)	16	Emas. and covered	0	74	Emas. and covered	0
N. tabacum var. *fruticosa*				77	Emas. and covered	0
N. tabacum var. *macrophylla purpurea*				33		

EXPERIMENTS ON THE ARTIFICIAL PRODUCTION OF APOMICTIC SEED IN THE GENUS NICOTIANA

For the simplification of the following subject matter, the experimental procedures used in the attempted production of parthenogenetic seed have been divided into four classes, namely, the effects of foreign pollen, of mutilation, of fumigation, and of injections.

The Effects of Foreign Pollen

Gärtner (Burbidge, 1877), while making species crosses, obtained seed in a few cases which produced plants true to the maternal species and also true hybrids. Mrs. R. H. Thomas (1909) and Professor E. M. East have also observed the same phenomenon in their work. Professor East's results were as follows:

Seed was obtained which produced plants like the mother species and also true hybrids, from crosses *N. paniculata*[4] × *N. alata* var. *grandiflora, N. rustica* × *N. tabacum,* and *N. tabacum* × *N. Bigelovii;* seed which produced plants like the mother species and no true hybrids, from crosses *N. paniculata* × *N. Langsdorffii, N. paniculata* × *N. longiflora, N. paniculata* × *N. Forgetiana,* and *N. Bigelovii* × *N. sylvestris;* and seed which produced no true hybrids on one occasion but did produce true hybrids on other occasions, from cross *N. tabacum* var. *lancifolia* × *N. alata* var. *grandiflora.* These crosses gave per capsule from one to twenty-five good seeds that produced plants true to the mother parent, and many angular and undeveloped seed that produced very few hybrids. In the cases where no hybrids were produced, abortive seeds—probably hybrid in character—were present.

These seeds, true to the mother species, are thought by Professor East to be due to adventitious embryos arising from the tissue of the nucellus, for no case of seed formation after simple castration occurred in some hundreds of experiments, nor did seed giving maternal plants arise in any but wide species crosses giving sterile or nearly sterile progeny. If such be the case, parthenogenesis did not occur in these crosses.

Pollen grains of certain species in the plant kingdom are known to be capable of instigating the development of parthenocarpic fruits and of polyembryonic seed of foreign species, but whether they can cause the parthenogenetic development of ovules is still a question; even

[4] The authorities for the specific names of the *Nicotiana* species used in these experiments are given on p. 23.

though varieties of *Vitis vinifera* have been noted by Millardet (1901) as giving only *Vitis vinifera* progeny, when pollinated by *Ampelopsis hederacea.* Examples of the parthenocarpic fruits, however, are common. The writer, while attempting to cross the tomato with the Jerusalem Cherry (*Solanum Pseudo-capsicum*) obtained parthenocarpic tomato fruits, but no fruit of any kind developed when the reciprocal cross was made. Parthenocarpic Seckel pear fruits were also produced by the application of Yellow Transparent apple pollen. In the crosses between *Nicotiana* species already mentioned, seed true to the mother parent was produced; but as in the case of the *Vitis vinifera,* there is no positive proof of a parthenogenetic development. What stimulatory effect is imparted by the pollen grain must be due either to an irritation caused by the entrance of the pollen tube or to the exudation of a "growth enzyme."

THE EFFECTS OF MUTILATION

The floral and axial organs of the plants were mutilated by emasculation, by the removal of the anthers, by decapitation, by the removal of both the stigmas and anthers, and by burning various portions of young buds, with the object of upsetting the normal functional processes in such a way as to incite the parthenogenetic development of seed. To simple emasculation and decapitation were added several modifications. Emasculated buds were covered with both paper bags and celluloid covers, but no advantages in favor of either covering could be detected. The decapitated buds were covered with the same two coverings, and in addition buds were left uncovered, but no differences in the results of these three methods were noted. Theoretically, the buds provided with the greatest amount of light and air should be favored in their development, but in this particular case, the results did not permit one to draw conclusions, since only negative results were obtained. Since capsules of *N. tabacum* were found to develop from pollinated flowers as well under the paper bags as under the

celluloid covers, the latter covering was soon discarded. The advantages of the paper bags are, first, they cover a great many buds and, second, they are put on and removed very easily.

Clusters of buds that had been emasculated as well as those that had been decapitated were also ringed a few inches below the buds. The operation was performed with the hope that the food stored above the injury would upset the natural equilibrium of nutrition in such a way as to cause the development of the ovules. In these ringing experiments only negative results were obtained, although Ewert found that injuries to gooseberry branches favored the development of parthenocarpic fruits.

Neither the tickling of *N. tabacum* buds, varying in size from small to large, with a camel's hair brush every half hour for five consecutive hours, nor the cutting of the bases of *N. suaveolens* and *N. commutata* buds, with the point of a scalpel, gave results. Professor East has, however, produced a slight swelling in the capsules, but no seeds, by occasionally tickling the buds of the following species with a sharp-pointed instrument—*N. tabacum* (vars. fasciated, Sumatra, broadleaf, and Havana), *N. alata, N. Bigelovii, N. Forgetiana, N. glutinosa, N. Langsdorffii, N. Langsdorffii* var. *grandiflora, N. longiflora, N. paniculata, N. plumbaginifolia, N. quadrivalvis, N. rustica* (vars. *humilis, brazilica,* and *texana*).

Stimulation was also attempted, as already noted, by burning or rather singeing buds varying in development from very young to nearly mature, with a heated platinum wire. The hot wire was applied to various portions of the buds, namely, to the base, to the top of the ovary, the stigma, and to both the stigma and the ovary. When the pistils were not injured, the blossoms were covered with bags, but covering was not considered essential when the pistils were made functionless. *N. Langsdorffi* var. *grandiflora* and *N. plumbaginifolia* gave no results, but one capsule of *N. tabacum* produced fifty-six apparently normal seeds—none of which germinated after a

period of several months' rest. The stage of maturity and the parts burned of each bud were not recorded and therefore the condition and exact treatment of this particular bud are unknown.

As a check on the uncovered decapitated pistils,[5] pollen from the same and other varieties was applied directly to the cut surface of the styles; in addition to pollen, cane-sugar solutions varying from 25 per cent. to 50 per cent. in strength,[6] stigmatic fluids, and in one instance nectar taken from the base of buds, were also applied. If the shortened pistils could be fertilized, it was thought that certain impossible crosses, as *N. alata* × *N. Forgetiana* and *Mirabilis Jalapa* × *M. longiflora* might be made, providing the difficulty existed in the extreme length of the styles. In one case, the applied stigmatic fluid and the pollen grains were taken from the same species. This precaution was used, as it was thought that the stigmatic fluid of one species might contain an enzyme or an inhibiting substance which would prevent the germination of foreign pollen grains. This supposition was supported by the growth of pollen grains in stigmatic fluids placed within Van Tieghem cells. For instance, the *N. glauca* pollen grains germinated and made good growth in the stigmatic fluid taken from *N. glauca* plants, while *N. suaveolens* pollen grains did not extend their pollen tubes in the stigmatic fluid taken from *N. Forgetiana*. If the tissue of the style contains an inhibiting agent, also, the germination of pollen grains on the cut style would be of no benefit. (This supposition may explain the negative results.[7])

[5] Ewert (1909) quotes Gärtner who states that Henschel obtained seven ripe fertile seed from six blossoms of *Salvia sclarea* whose pistils had been destroyed, and four abortive seeds from three capsules of *Polemonium gracile* whose pistils had also been destroyed.

[6] A 33⅓ per cent. strength was used in the later work, as the pollen grains of *N. glauca*, *N. longiflora* and *N. tabacum* germinated readily and made good growth in this solution.

[7] The presence of one or more inhibiting agents might be used to explain the failure of grafts between plant species, for they may act like the antibodies, produced in animals by the transference of the blood of one species to that of another, and cause death.

Whether the pollen tubes in these experiments reached the ovules is not known, but probably not, since no fertile seed was produced. The production of numerous seed normal in appearance indicates, however, either that the pollen tubes must have stimulated the nucellus tissue in some way, or that normal seed development was started but not finished, for no seed of any kind was produced in the decapitated blossoms where pollen grains were not applied.

The total abortive seed produced by the pollination of the decapitated styles included two from *N. tabacum* where the stubs were covered with 50 per cent. cane sugar solution and self-pollinated, four from the same species where the stubs were covered with stigmatic fluid and self-pollinated, twenty-seven from *N. paniculata* where the stubs were covered with stigmatic fluid and self-pollinated, and fourteen from *N. tabacum* where *N. Forgetiana* pollen and no fluid was applied.

In connection with the decapitation experiments, an experiment on the grafting of pistils[8] was conducted. One hypothesis for the non-crossing of certain species, as has already been mentioned, is the extraordinary length of the style. By removing a portion of the style and grafting the stigma end of a pistil of either the same or another species to the stub, the style was shortened from one to one and a half inches. Immediately after grafting, the stigmas were pollinated. From one of the five grafted *N. tabacum* blossoms was produced one abortive seed. The development of this one seed may or may not have been due to the penetration of one or more pollen tubes, as in the cases where pollen grains were applied directly to the decapitated pistils.

[8] The grafting technique is simple, nevertheless, the operation is difficult, owing to the small size of the styles. A light splinter was first attached to the base of the style by means of collodion, then the upper portion of the style was removed with a sharp knife. The end of the pistil to be grafted on the stub was cut off at the same angle and placed on the stub and made fast with the collodion.

MUTILATION EXPERIMENTS—FORCING HOUSE

TABLE II

Species	No. Clusters	No. Buds	Treatment	Stig. Fluid	Pollen	No. Seed	Remarks
N. alata var. *grandiflora*	2		Decap.	Self	*N. Forgetiana*	0	
N. alata var. *grandiflora*	1		Decap.	Self	*N. Sandaræ*	0	
N. alata var. *grandiflora*	2		Decap.	Self	Self	0	
N. alata var. *grandiflora*	2		Decap.	33⅓ per cent. sugar	*N. Forgetiana*	0	
N. alata var. *grandiflora*	2		Decap.	33⅓ per cent. sugar	*N. Langsdorffii*	0	
N. alata var. *grandiflora*	1		Decap.	33⅓ per cent. sugar	*N. Sandaræ*	0	
N. alata var. *grandiflora*	1		Decap.	33⅓ per cent. sugar	Self	0	
N. Forgetiana	1		Emas. and covered			0	
N. Forgetiana	1		Decap.	*N. Langsdorffii*	*N. Langsdorffii*	0	
N. glauca	3	5	Emas. and covered			0	
N. glauca	2		Decap.			0	
N. glauca	1		Decap. and bagged			0	
N. glauca		3	Hot pt. wire and emas.			0	Singed stigmas.
N. Langsdorffii		5	Decap.	Self	*N. Forgetiana*	0	
N. Langsdorffii	1		Decap.	33⅓ per cent. sugar	*N. Forgetiana*	0	
N. Langsdorffii	2		Hot pt. wire and emas.			0	Singed base of buds.
N. Langsdorffii	1		Cut and emas.			0	Cut base of buds with scalpel point.
N. paniculata	4	12	Emas. and bagged			1	Seed abortive.
N. paniculata	5	5	Decap. and bagged			0	
N. paniculata		3	Decap.	Self	Self	27	Seed abortive.
N. paniculata	2		Decap.	25 per cent. sugar	*N. Tabacum*	0	
N. paniculata	4		Hot pt. wire and emas.			0	Singed stigmas.
N. plumbaginifolia	2		Hot pt. wire and emas.			0	Singed base of buds.

TABLE II (*Continued*)

Species	No. Clusters	No. Buds	Treatment	Stig. Fluid	Pollen	No. Seed	Remarks
N. Sandarae	1		Decap.			0	
N. Sandarae	1		Decap.	Self	*N. Forgetiana*	0	
N. suaveolens		3	Decap.	Self	*N. Forgetiana*	0	
N. suaveolens	1		Cut and emas.			0	Cut base of buds with scalpel point.
N. tabacum	5	12	Decap. and covered			0	
N. tabacum	2		Decap. and bagged	0	*N. Forgetiana*	14	Seed contained in one locule.
N. tabacum	3	28	Decap. and bagged	0	Self	6	Three seeds in one capsule and one seed in other capsules.
N. tabacum	14	10	Emas. and covered			0	
N. tabacum	1	15	Emas. and ringed			0	
N. tabacum		8	Emas. and tickled			0	
N. tabacum	1		Decap. and grafted		Self	1	
N. tabacum	2	2	Decap. and ringed			0	
N. tabacum	1	1	Decap.	33⅓ per cent. sugar	*N. Forgetiana*	0	
N. tabacum	1	1	Decap.	50 per cent. sugar	*N. glauca*	0	
N. tabacum	1	2	Decap.	50 per cent. sugar	Self	2	Seed found in one capsule.
N. tabacum	1	1	Decap.	Nectar	Self	0	
N. tabacum		14	Hot pt. wire and emas.			56	Singed stigmas. Seed borne in one capsule.
N. tabacum	1	4	Hot pt. wire and emas.			0	Singed both stigmas and ovaries.

The mutilation experiments all proved to be valueless in the production of fertile seed; nevertheless, they were interesting, since they were the only methods, except where actual crosses were made and where chloroform gas was used, which caused any seed development.

(See Table II—Mutilation Experiments.)

EFFECTS OF FUMIGATION

Several species, the names of which are listed in Table III, were exposed before the plants had reached the flowering stage to gases given off by acetone, carbon tetrachloride, chloroform, ether, ethyl acetate, ethyl bromide, ethyl chloride, ethyl iodide, and formaldehyde. As in the previous experiments, the buds were emasculated and bagged. The object of this experiment, as of the one on mutilation of the plants, was to endeavor to upset the normal development of the floral organs in such a way as to cause the production of seed without the aid of fertilization.

The methods used in conducting this experiment were simple. Plants, growing in six-inch pots, were fumigated approximately one seventh of a cubic foot when drawn in at the top. The bags were closed either around the stems which had been previously surrounded with cotton batting or about the top of the pots, the method of treatment depending on the height of the plants. When everything was in readiness for fumigation, the gas was set free by the opening of the vial which was glued to the interior of the bag. Though the seams and the bottoms of the bags were sealed by melted paraffine, the retention of all the gas was not expected. A sufficient quantity was present, however, when acetone and formaldehyde were used, for the foliage of the plants, treated with these gases, to become noticeably injured.

TABLE III

FUMIGATION EXPERIMENTS—FORCING HOUSE

Species	Ht. Plant, In.	Liquid	C.c per Cu. Ft.	Hrs. Exposed	No. Seed	Remarks
N. alata var. *grandiflora*...	3	Ethyl acetate	8	24	0	Leaves drooped, three capsules developed.
N. alata var. *grandiflora*...	1½	Ethyl acetate	12	24	0	Leaves drooped.
N. Bigelovii.....	4	Acetone	12	40	0	Several leaves injured.
N. Bigelovii.....	2¼	CCl_4	12	40	0	Slight injury.
Dewey's Sport No. 1.....	5	Ethyl acetate	4	43	0	No injury.
Dewey's Sport No. 1.....	9¾	Ethyl acetate	4	72	0	No injury, six capsules developed.
Dewey's Sport No. 1.....	4¼	Ethyl acetate	6	43	0	No injury.
Dewey's Sport No. 1.....	9¾	Ethyl acetate	6	72	0	No injury, three capsules developed.
Dewey's Sport No. 1.....	5	Chloroform	2	43	0	No injury.
Dewey's Sport No. 1.....	12¼	Chloroform	2	72	0	One capsule had six locules, six capsules developed.
Dewey's Sport No. 1.....	4	Chloroform	4	43	0	No injury.
Dewey's Sport No. 1.....	9⅝	Chloroform	4	72	0	No injury, one capsule developed.
Dewey's Sport No. 1.....	6	Formaldehyde	4	43	0	
Dewey's Sport No. 1.....	13½	Formaldehyde	4	72	0	Five capsules developed.
Dewey's Sport No. 1.....	3¾	CCl_4	4	43	0	No injury.
Dewey's Sport No. 1.....	9⅛	CCl_4	4	72	0	No injury, four capsules developed.
Dewey's Sport No. 1.....	5½	CCl_4	6	43	0	No injury.
Dewey's Sport No. 1.....	11¼	CCl_4	6	72	0	No injury, five capsules developed.
N. Forgetiana.....	1½	Formaldehyde	8	72	0	
N. longiflora.....		Ethyl chloride	12	24	0	Four capsules developed.
N. longiflora.....	Sessile	Ethyl iodide	12	24	0	
N. longiflora.....	Sessile	Ethyl iodide	12	24	0	Two capsules developed.
N. longiflora.....	2¾	Ethyl acetate	12	24	0	Two capsules developed.
N. longiflora.....	Sessile	Ethyl acetate	12	24	0	Four capsules developed.
N. paniculata.....	4½	Ethyl bromide	2	22	0	No injury.
N. paniculata.....	5	Ethyl bromide	4	22	0	No injury.
N. paniculata.....		Ethyl bromide	6	20	0	Cover a bell-jar—not a paper bag.
N. paniculata.....	6¾	Ethyl bromide	8	72	0	No injury.
N. paniculata.....	6¼	Ethyl bromide	12	72	0	No injury, seven capsules developed.
N. paniculata.....	6	Formaldehyde	4	20	0	
N. paniculata.....	7	Formaldehyde	2	20	0	
N. paniculata.....	5½	Acetone	2	22	0	Slight injury to foliage.
N. paniculata.....	7	Acetone	4	22	0	No injury to foliage.
N. paniculata.....	10½	Chloroform	1	22	2	No injury, one capsule developed.
N. paniculata.....	10	Chloroform	2	22	0	No injury.
N. paniculata.....	11	Ether	4	22	0	No injury.
N. plumbaginifolia.....	Short	Ether	12	24	0	
N. plumbaginifolia.....	Short	Ether	12	24	0	
N. plumbaginifolia.....	10½	Ethyl iodide	8	24	0	
N. plumbaginifolia.....	14½	Ethyl iodide	8	24	0	
N. plumbaginifolia.....	1½	Ethyl bromide	12	40	0	One capsule developed.
N. quadrivalvis.....	8¼	Ethyl bromide	12	24	0	No injury, one capsule developed.

TABLE III (*Continued*)

Species	Ht. Plant, In.	Liquid	C.c. per Cu. Ft.	Hrs. Exposed	No. Seed	Remarks
N. quadrivalvis	9½	Ethyl bromide	12	24	0	No injury, two capsules developed.
N. quadrivalvis	8	Ethyl bromide	8	24	0	No injury, two capsules developed.
N. quadrivalvis	10	Ethyl bromide	8	24	0	No injury.
N. quadrivalvis	7	Ethyl chloride	12	24	0	Three capsules developed.
N. quadrivalvis	6	Ethyl chloride	12	24	0	Three capsules developed.
N. quadrivalvis	9	CCl_4	4	22	0	No injury.
N. quadrivalvis	12	CCl_4	2	22	0	No injury.
N. rustica var. *texana*	6¼	Acetone	4	43	0	No apparent injury.
N. rustica var. *texana*	20⅝	Acetone	4	72	0	Terminal growth injured, four capsules developed.
N. rustica var. *texana*	9	Acetone	6	43	0	Terminal leaves, slightly injured.
N. rustica var. *texana*	21¼	Acetone	6	72	0	One leaf injured, four capsules developed.
N. rustica var. *texana*	5	Ethyl bromide	4	43	0	No injury.
N. rustica var. *texana*	17	Ethyl bromide	4	72	0	No injury, seven capsules developed.
N. rustica var. *texana*	5¾	Ethyl bromide	6	43	0	One leaf slightly injured.
N. rustica var. *texana*	17½	Ethyl bromide	6	72	0	One terminal blossom leafy, six capsules developed.
N. rustica var. *texana*	7	Ether	4	43	0	No injury.
N. rustica var. *texana*	15¾	Ether	4	72	0	Terminal bud injured and produced leafy blossom. Eight capsules developed.
N. rustica var. *texana*	6¾	Ether	6	43	0	No injury.
N. rustica var. *texana*	18	Ether	6	72	0	No injury, thirteen capsules developed.
N. Sandaræ		Chloroform	8	24	0	No injury, three capsules developed.
N. Sandaræ		Chloroform	12	24	0	No injury, one capsule developed.
N. sylvestris	Sessile	Chloroform	12	24	0	Leaves (outer) turned yellowish after two days.
N. sylvestris	Sessile	Chloroform	12	24	0	
N. sylvestris	Sessile	Ether	8	24	0	
N. sylvestris	Sessile	Ether	8	24	0	
N. sylvestris	Sessile	CCl_4	12	24	0	No injury.
N. sylvestris	Sessile	CCl_4	12	24	0	No injury.
N. tabacum var. *fruticosa*	11	Ether	8	72	0	No injury.
N. tabacum var. *fruticosa*	5½	Ether	12	72	0	No injury.
N. tabacum var. *fruticosa*	7¼	CCl_4	8	72	0	No injury.
N. tabacum var. *fruticosa*	5⅜	CCl_4	12	72	0	No injury.
N. trigonophylla	5	Ethyl bromide	12	40	0	
N. trigonophylla	1½	Acetone	12	40	0	Leaves injured.
N. trigonophylla	3½	CCl_4	12	40	0	No injury.

Untreated plants of all of the above species were held as checks on the results of each test. A *N. rustica* var. *texana* plant produced one leafy terminal blossom, otherwise, all the plants were normal.

A *N. paniculata* plant treated with chloroform gave two abortive seeds, but none of the other species produced a seed. *N. rustica* var. *texana,* however, after two exposures to acetone vapor underwent very marked morphological changes in the structure of the terminal blossoms, both of the main and of the lateral stems. In other words, the most exposed buds suffered the greatest injury. As the ether, ethyl bromide, and check treatments produced one blossom apiece which was similarly affected, and no other species, even though treated with acetone, was injured in the same way, indicates that the *N. rustica* var. *texana* floral parts are somewhat unstable. This opinion is substantiated by Penzig who in his *Pflanzen-Teratologie* cites observations where *N. rustica* blossoms have been modified to such a degree that the petals have turned green and where five blossoms have been compressed into a common calyx. Perhaps the presence of a small amount of chlorophyll in the greenish yellow corollas is an indication of a close relationship of the petalous to the leafy condition. Even though the *N. rustica* blossoms are easily modified, it is very evident that the acetone vapor caused a disturbance in the natural development of the floral organs, for the two treated plants were affected in the same way and degree. The calyxes, corollas and stamens were modified markedly, while the carpels and pistils and most of the stamens were usually normal in appearance. For instance, in some cases the calyxes were fused together and enlarged to such a size that they resembled distorted and crinkled leaves. One blossom had three sepals fused to the corolla and two sepals located one half inch below the base of the blossom. The lower two had a node as distinct as any leaf on the branch, and within their axis were borne two small buds, which lacked calyxes. One of the upper three sepals also bore a similar naked bud in its axis. It may be that in this case the acetone vapor stunted the branches in such a way that many latent buds were present in a very small space. The corollas

in some cases were entirely replaced by small green leaves—smaller than the sepals—and in other cases they were partially replaced by leafy tissue. A few stamens had their filaments flattened and their anthers replaced by a small green leaf. These changes might be advanced, as an evidence of the evolutionary development of the floral organs, if the theory that these organs are simply modified leaves and that reversions are frequently caused by injuries were not already so well substantiated. Whether any mutations might have occurred in the progeny produced from these blossoms is unknown, as fertilization of the ovules was not attempted. No parthenogenetic seed was obtained from these injured blossoms, and this might have been expected, since leafy formations in the blossoms are generally accompanied by sterility.

EFFECTS OF LIQUID INJECTIONS

The forcing of liquids into the plants was performed with the same object in view as in the preceding experiments, viz., to endeavor to stimulate cell division and thus possibly produce unfertilized seed. To certain liquids has been ascribed the power of being able to cause mutations when injected into the buds of certain plants, but in this experiment all the injections were made directly into stems of plants, eight to twenty inches in height.

The apparatus used was simple. Glass capillary tubes were connected by rubber tubing to glass tubes, about 30 inches long and about one quarter inch in diameter, which contained the liquids. The rubber tubing permitted the stems to lengthen without disturbing the operations. The end of the capillary tube was inserted from one eighth inch to one quarter inch into the stem, the distance depending upon the diameter of the stems and 1 inch to 15 inches below the terminal bud. An application of collodion held the capillary tube in place and stopped all leakage. After having supported the tube, the pinch-

cock—previously fastened to the rubber tubing—was released and the liquid flowed into the stem as rapidly as it could be used by the plant. The injection was assisted by the weight of its own column, and, in the most cases, by the addition of a short column of mercury, suspended by the surface tension of the liquid. The use of the mercury required considerable care, for when the surface tension was overcome by a jar, the mercury sank to the bottom and plugged the capillary tubes.

The treated species were: *N. tabacum* var. *fruticosa, N. paniculata, N. Langsdorffi* var. *grandiflora, N. Langsdorffii, N. alata* var. *grandiflora, N. attenuata,* and *N. Sandaræ.*

The materials used for the injections are: Sodium phosphate, butyric and valeric acids, ethyl acetate, acetone, benzol, chloroform, formaldehyde, methyl blue, saffranin and thiazin. The last three are simply stains and were used to trace the course of the liquids. The coloring matter was found to follow the vascular bundles of the stems and the leaves for several inches, and yet the slightest trace was not discovered in the buds. Acetone, butyric, and valeric acids of .5 per cent. strength caused severe injury, formaldyhyde at 2 per cent. caused a slight injury to the foliage, but no other liquid caused a noticeable disturbance.

All the treated plants, as in the previous experiments, had at least one cluster of buds emasculated and bagged, but all to no purpose, since not even one abortive seed developed.

Summary

1. Seed giving plants true to the maternal species in the F_1 generation accompanied by aborted seed probably hybrid in nature, was found when certain *Nicotiana* species were cross-fertilized. Hybrid plants and plants purely maternal were obtained from the same capsules in other crosses.

2. The capsules of several *Nicotiana* species were

caused to swell slightly by merely tickling them with a sharp-pointed instrument, but no seeds were produced.

3. Abortive seed probably without embryos was produced by singeing young buds with a hot platinum wire, by the exposure of young plants to chloroform gas, and by cutting away a portion of the pistil and pollinating the stub both with and without the accompaniment of a germinative fluid.

4. Abortive seed was produced by shortening the pistils of a flower and grafting the stigma end of another pistil on to the stub and pollinating the same.

5. The ringing of the branches below a cluster of buds did not assist in the production of seed.

6. No seed was produced by the simple methods of emasculation and decapitation of blossoms, except in one doubtful case of *N. plumbaginifolia.*

7. It is likely that an agent inhibitory to the growth of pollen grains is present in the stigmatic fluids of certain species of the genus *Nicotiana;* at least, the pollen grains of *N. suaveolens* did not germinate in *N. Forgetiana* stigmatic fluid when placed within a Van Tieghem cell.

8. The exposure of young *N. rustica* var. *texana* plants to acetone gas caused the transformation of the corollas and the stamens of most of the terminal flowers into leafy tissue; otherwise, except in the mentioned case of the chloroform, no results were secured by the use of anaesthetic and toxic gases.

9. The injection of chemicals into the stems of tobacco plants was valueless in the production of seed.

10. As no unquestionable case of parthenogenetic seed was produced in the several hundred trials, it seems very improbable that parthenogenesis exists in the genus *Nicotiana*—at least in the species tested. The seed obtained in the crosses which came true to the mother species is probably polyembryonic—the stimulus of development being imparted either by the penetrating pollen tubes or by a substance exuded from the same.

NICOTIANA SPECIES USED IN THE EXPERIMENTS

N. alata Lk. & Otto var. *grandiflora* Comes.
N. attenuata Torr.
N. Bigelovii Wats.
Dewey's Sport No. 1.
N. Forgetiana Sand.
N. glauca Grah.
N. glutinosa L.
N. Langsdorffii Weinm.
N. Langsdorffii Weinm. var. *grandiflora* Comes.
N. longiflora Cav.
N. paniculata L.
N. plumbaginifolia Viv.
N. quadrivalvis Pursh.
N. rustica L. var. *brazilica* Schrank.
N. rustica L. var. *humilis* Schrank.
N. rustica L. var. *texana* Comes.
N. Sandaræ Hort. (hybrid).
N. suaveolens Lehm.
N. sylvestris Speg & Comes.
N. tabacum (broadleaf).
N. tabacum (calyciflora).
N. tabacum (fasciated).
N. tabacum (Havana).
N. tabacum L. var. *fruticosa* Comes.
N. tabacum var. *lancifolia* (W.) Comes.
N. tabacum L. var. *macrophylla purpurea.*
N. tabacum L. (Sumatra).
N. trigonophylla Dun.

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SHORTER ARTICLES AND DISCUSSION

SIMPLIFIED MENDELIAN FORMULÆ

I WAS somewhat surprised by Morgan's and Castle's suggestions for a simplification of Mendelian formulæ.[1] My surprise was not occasioned so much by the forms these suggestions took as by the fact that any pronounced changes were deemed necessary. I had not only employed the usual formulæ in my own work but had found no difficulty worth mentioning in understanding the formulæ used by most other workers in Mendelian fields. My experience with students in elementary courses in genetics had not prepared me for the idea that such formulæ were particularly difficult. Nevertheless I believe in simplifying the formulæ if some system can be found that will be applicable to all sorts of Mendelian inheritance. I believe, however, that I have no right to adopt formulæ for my own cases, no matter how simple they might be, if the same type of formula could not readily be applied to the materials with which other investigators are working. Such procedure on my part would result in no end of confusion if followed by any considerable number of workers each using his own special type of formula. The important question now is not whether I prefer a new style of formula that fits my case but whether it will fit all sorts of cases so that, if it is an improvement on the old style, it can be adopted by others and not necessitate the use of two styles where but one sufficed before.

Let us examine Morgan's and Castle's suggestions in the light of these remarks. Morgan's principal objection to the usual type of formula—that "it is not sufficiently elastic to allow the introduction of a new term in the series, unless a complete revision of the method is made each time that a new mutation in kind occurs"—seems to me to have little merit. Morgan uses eye color in *Drosophila* to illustrate his contention. Four eye colors had been designated as follows: red *PVO,* vermilion *pVO,* pink *PvO,* and orange *pvO.* A fifth color, eosin, arose and was found to produce red when crossed with orange, and hence was assumed to have the formula *PVo.* Morgan regards this as "inconsistent with the scheme already adopted because the small letter *o* stands for a character called eosin," whereas the capital letter *P* had been used for pink, *O* for orange, *V* for vermilion,

[1] AMERICAN NATURALIST, 47: 5–16, and 47: 170–182, 1913.

etc. Morgan's trouble lies in the fact that he is attempting to force a letter to represent a *character* rather than merely one of the *factors* concerned in the development of that character or to represent the character and one of the factors. As a matter of fact, in the formula *PVo*, the character eosin is not represented by *o* but by *PV* when *O is absent* (with the addition, perhaps, of many factors as yet unknown). Similarly *P* does not stand for pink but for *one* of the factors concerned in the production of pink. One of the other factors concerned in the development of pink Morgan has identified and named *O*; there are probably other factors as yet unidentified. For orange he has identified only a single factor and that is this same *O*. No one has shown more clearly than Morgan that a character is not *determined* by a single factor. Why then should it be thought necessary to designate the first factor identified for any character, say pink, by the initial letter of that word? It is quite likely that *P* is no more important in the production of pink than is *O*. And it is equally probable that *O* is no more concerned in the development of orange than are perhaps a half dozen other factors not yet identified. The logical thing in such cases is to adopt Baur's $A \cdot B \cdot C \cdot$ designations, which fit in readily with current Mendelian usage. True, as Morgan insists, this necessitates the constant use of a key. But what system does not? What is there in Morgan's *PVO*, or even in his later *PVE*, to suggest red color?

It is fortunate that Mendelians "have not always taken the pains to state explicitly that the symbols represent both a factor and a residuum," for this, it seems to me, is not true. The residuum left when any factor is lost is usually not represented except by the few factors that have been identified in it. It is careless without doubt to leave so much to be taken for granted, but it would be cumbersome to have to write for pink

$$PvOX_1X_2X_3 \cdots X_n.$$

Perhaps we might use a single X to represent an unknown number of unidentified factors, or perhaps it would be as well to use *UR* for this unexplored residuum.

I am inclined to agree fully with Castle that Morgan's suggestion for a change in the current Mendelian formulæ is "confusion worse confounded," but here our agreement stops. I can see that it might be possible to do away with the use of small letters, since on the presence-and-absence hypothesis they represent nothing but the absence of factors designated by the corresponding capital letters. The designations of eye colors in

Drosophila (if we adapt Morgan's earlier scheme) would then become *PVO, VO, PO, PV* and *O*, instead of *PVO, pVO, PvO, PVo* and *pvO*, for red, vermilion, pink, eosin and orange respectively. The great difficulty in thus leaving out the small letters comes in distinguishing the heterozygous from the homozygous condition. True we can let *PVO* stand for the heterozygous condition of the three factors and *PPVVOO* for the homozygous condition. Then *PPVO* would indicate what is now commonly expressed by *PPVvOo*. But we now use the single letters when we wish merely to designate *phenotypic* differences or to indicate the factors in gametes, where of course all factors are simplex, and employ duplicate letters only when we desire to indicate *genotypic* differences. If then the small letters are discarded, we shall need to use some arbitrary sign to distinguish phenotypes from genotypes, else *PVO* might as now stand for a group of phenotypically like individuals or for a class having the genotypic constitution now commonly indicated by *PpVvOo*.

But Castle's suggestion is far from what is outlined above. He would use no letter to represent red eye color in *Drosophila* but merely write *normal*. For vermilion he would use *v*, for pink *p*, for pink-vermilion *pv*, etc. My first notion on reading the list of designations for eye color in fruit flies was that Castle used them only as abbreviations for the names of the colors, and *v* is really a better abbreviation for vermilion than is say Verm. or V'r'm'l'n. Now why, I thought, should one suggest such *character* abbreviations as a revised *Mendelian* terminology when Mendelism is concerned fundamentally with *gametic* factors and only incidentally with the *zygotic* characters that happen to develop through the interaction of particular combinations of gametic factors in a particular environment. But Castle's terminology is not concerned with mere abbreviations for characters, as witness:

> The revised terminology is more convenient than Morgan's in calculating the expected result of any mating, and is equally reliable. The results of every possible mating within the series can be readily computed without the confusing presence of the large letters.

Here I must frankly admit that I have experienced great difficulty in using Castle's terminology in calculating the expected results of matings in case of the eye colors in *Drosophila*, though this is probably due to some misunderstanding of just how Castle's formulæ are to be used. For instance, a cross of *v* (vermilion) with *p* (pink) should, if ordinary usage were fol-

lowed, produce *vp* (vermilion-pink) whereas it actually produces red.

The use of capital letters for dominant factors and small letters for recessive ones, while it may work well in some cases, would be difficult of application in others. Brown color in beans is dominant[2] to yellow but recessive to black. Shall we then use *B* or *b*? True, Castle limits the use of the capital letter to the "factor responsible for a variation which is dominant in crosses with the *normal*" (italics mine), but who is to say what is the normal color of beans? The use of capital letters for some characters and small letters for others is, however, a minor matter and would not alone disqualify the proposed terminology.

When one is considering any new scheme, it is natural that he should try it out on material with which he is familiar. I have, therefore, attempted to apply Castle's suggestions to aleurone colors in maize. To make the matter as simple as possible, I will leave out of consideration color patterns and also the various dilutions or intensities of color and limit myself to the statement that aleurone may be purple, red, or white. In an account of certain crosses published last year[3] I made use of the symbols suggested by East and Hayes: *C* a general color factor, *R* concerned with *C* in the production of red, *P* resulting in purple when both *C* and *R* are present, and *I* an inhibitor of color development. I listed 14 kinds of white aleurone.[4] Now if we were to adapt Castle's formulæ for albino mice to these white maize types, we might use *wP* for whites transmitting purple in crosses, *wr* for whites transmitting red, and *wPr* for those transmitting both purple and red. But there are seven kinds of whites, all of which might yield purples in appropriate crosses with non-purples. How shall we distinguish between them? Of course we could add to *w* the letters *C, R, P, I* or such ones of these as might be necessary to indicate the factors latent in a particular white, but *wCRPI* is no improvement over *CRPI* from the standpoint of simplicity. Students in elementary courses in genetics who have used maize for laboratory material have had little trouble in calculating that when a white maize *CCrrPpIi* is crossed with another white maize *ccRRPpIi* there

[2] On the presence-and-absence hypothesis it is hardly allowable to speak of the relation of two non-allelomorphic characters in terms of dominance. Brown is epistatic to yellow and hypostatic to black. Each is dominant to its own absence.

[3] AMERICAN NATURALIST, 46: 612–615, 1912.

[4] I now have much additional evidence for my assumption as to the different sorts of white aleurone.

should result, on the average out of every 16 grains in the first generation, 3 purple, 1 red and 12 white grains. I do not doubt that the calculation could be made with equal rapidity and accuracy if the small letters were omitted and the capital letters used in the same significance. The cross would then be: *CCPI* × *RRPI*. The greatest difficulty with this plan would come in designating the white now known as *crpi*, unless we employ a mere dash, ——. It is possible that there is some simple way of applying Castle's scheme to such a case as this, a way which I have stupidly overlooked or perhaps I have not understood the scheme at all. If there is some simple terminology that is workable, I shall be glad to use it, but I must confess to being suspicious of very simple formulæ for the complex phenomena of inheritance.

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THE INFLUENCE OF THE DEVELOPMENT OF AGRICULTURE IN WYOMING UPON THE BIRD FAUNA

WYOMING is an interesting field of inquiry for the zoologist, not only because it is new and unexplored, but because changing agricultural conditions in the state have unbalanced the fauna, so that new adjustments are taking place.

This is particularly true of the birds, and since going to the state two years ago, I have been collecting data from various sources to learn to what extent the former distribution of the birds has been affected.

The larger part of Wyoming remains practically unchanged as yet by the presence of man, but numerous towns have sprung up, with the attendant planting of shade trees, which furnish good nesting places for birds, and the same may be said of the ranches. It is in these restricted areas that the changes in adjustment may be expected to be most manifest.

Again the increased raising of grain in many localities has produced a more abundant food supply for birds which live largely upon seeds.

Old residents of the state, and collectors whose experience extends over a period of several years, are almost universally of the opinion that certain birds are much more abundant now than formerly. In their replies to circular letters sent out, they have frequently specified the species which have been affected in this way. It will be readily seen that those men-

tioned are the ones which would be expected to show the influences of the factors indicated above. Those most frequently mentioned as having increased in numbers include the robin, meadow lark, bluebird, mourning dove, crow, grackle and cow birds.

Many birds which were reported as rare in W. C. Knight's "Birds of Wyoming," published in 1902, are now reported by collectors as being fairly common. It seems, therefore, that Wyoming is rapidly becoming a more hospitable place for birds in general.

There is considerable evidence to show that the quail has only recently migrated into the state, and that its migration was from Nebraska up the valley of the Platte River. At present it has penetrated as far as the mouth of Horse Shoe Creek on the Platte and as far as Uva on the Laramie River, which is a tributary of the Platte. The quail seems to have appeared in Wyoming first about 1890, and one informant thinks that it dies off during the winters from lack of food, and is prevented from further migration into Wyoming only because of lack of seeds.

A similar evidence of the effect of food supply upon the presence of birds in the state is given by Stanley Jewitt, a government collector, who says:

> I have found some kinds [of birds] very common in the more cultivated sections of Idaho and Wyoming during the last three years that were almost, if not entirely, unknown a few years ago. Such birds as the bobolink, yellow-headed blackbird and lark bunting, follow the farmer as soon as irrigation systems are completed.

One of the most interesting points ascertained is in regard to the English sparrow. In reply to a query as to whether there are any isolated towns in Wyoming to which this sparrow has not yet found its way, Professor B. C. Buffum replied that there seem to be none of these sparrows in some of the smaller interior towns, such as Tensleep and Nowood.

About ten or fifteen species of birds new to the state have been reported since the publication of Professor W. C. Knight's book in 1902. It is hardly possible that these have all come into the state since that time. Most of them had probably been overlooked before, but however this may be, new birds can be expected to enter the state from time to time, and certain of those already there will become more numerous as conditions are made more favorable for their existence.

The quotations which follow are indicative of the source and

reliability of the information from which the data of this paper were taken. They are extracts from letters received in reply to questions sent out by the writer. They are representative of the letters received from people who have had wide experience in the state. I think the conclusion that the changed conditions in the state in respect to increased raising of grain, tree planting and the irrigation of large tracts have been the direct cause of the increase in the number of birds, is justified. An increase which has been so marked that residents of the state in general have noticed and commented upon it.

Quotations from Letters Received

1. From William Richard, taxidermist, Cody, Wyo.:

It has been my opinion for several years that the birds are on the increase, excepting the sage hens, ducks and eagles, which seem to be decreasing.

2. From Louis Knowles, forest supervisor, Sundance National Forest, Sundance, Wyo.:

There has been a marked increase in the number of birds in this region during the last ten or fifteen years. The increase has been in numbers and not in species. The increase is undoubtedly due to the gradual increase of cultivated areas.

With Reference to the Quail

3. From John Hunton, one of the oldest and best informed citizens of Wyoming, Fort Laramie, Wyo.:

The quail of the bob white species first made its appearance in the Wyoming section of the Platte Valley at the Wyoming-Nebraska line in the summer of 1890. They have gradually worked up the valley until reaching the vicinity of Guernsey. They have also worked up the Laramie River to the neighborhood of Uva. They are not and have not been numerous, being pioneers, as it were. During the winter of 1908–09 a covey of twenty-two frequented my yard here and fed with my chickens. On last Friday morning, June 14, I heard two bob whites on my meadow at Gray Rocks on the Laramie River, ten miles west of here. Occasional coveys are to be seen or heard along the valleys of both rivers as far as I have indicated. The quail evidently followed the course of the Platte Valley from Nebraska, and they are gradually working farther up the tributaries of the Platte as fast as the grain belt advances. I believe the cultivation of the soil to grains of various kinds is the only thing which has induced them to migrate west.

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NOTES AND LITERATURE

THE DEPTHS OF THE OCEAN[1]

THE publication of this work marks an epoch in the advance of the science of oceanography second only to that initiated upon the return of the *Challenger* Expedition, but while the explorations of the *Challenger* were extensive and of necessity somewhat superficial, these later studies conducted by the *Michel Sars* are predominately intensive and thorough.

Not the least valuable of the lessons the book teaches us is the fact that through the skillful and courageous use of a small vessel by trained experts, results of the highest value to science may yet be achieved.

One admires the courage of the leaders of this expedition who ventured to cross and recross the Atlantic in a little steamer only 125 feet in length, and with a coal supply capable of carrying her only 3,400 miles at the economical speed of 9 knots.

The cruise was evidently conducted under the most auspicious conditions respecting its management, the Norwegian government providing the vessel, while Sir John Murray supplied the funds necessary for the expenses of the expedition; and it may be well to recall the fact that the most successful expeditions of the United States Fish Commission steamer *Albatross* were conducted under a somewhat similar arrangement between the late Dr. Alexander Agassiz and the government.

Thus the ripe experience of the veteran leader in this field of research, Sir John Murray, was enlisted to perfect the methods of such active young students of oceanography as Dr. Hjort and his able associates, Professors Koefoed, Gran, and Helland-Hansen, all of whom accompanied the expedition.

The cruise lasted from April until August, 1910, extending from Plymouth to Gibraltar, thence to the Canaries and then to the Azores, from which region a run was made into the Sargasso Sea and on to Newfoundland, and thence to Glasgow and Bergen.

The book before us is, however, far more than an account of this cruise, rich as its results are in achievement in new fields, for it is actually an epitome of all results hitherto attained in

[1] A general account of the modern science of oceanography based largely on the scientific researches of the Norwegian steamer *Michel Sars* in the North Atlantic; by Sir John Murray, K.C.B., F.R.S., etc., and Dr. Johan Hjort, Director of Norwegian Fisheries, with contributions from Professor A. Appellöf, Professor H. H. Gran, and Dr. B. Helland-Hansen, xx + 821 pp., 575 figures. Macmillan and Co., Limited, London.

oceanography, and is thus comparable with Agassiz's "Three Cruises of the *Blake*" of 1888.

The first thing which strikes one upon reading this account of the cruise of the *Michel Sars,* however, is the enormous advance which has been made since Agassiz wrote his well-known work.

The book is written in that plain, honest English which the readers of Darwin learned to love so well. It is difficult to review because so crowded with facts of the highest interest, and it sparkles with that rare enthusiasm which characterizes the writings of those happy men of science to whom years and knowledge bring no lessening of youth's enthusiasm. At times the language seems quaint, for most of the chapters were written by students to whom English is not a native tongue; but this only adds to the readableness of the book. Indeed, it is a work which people of general culture as well as specialists may read with sustained interest from cover to cover. It is a fitting monument to the life-work of the great "Naturalist of the *Challenger* Expedition," Sir John Murray.

The historical chapter, and that upon the depths of the ocean are by Sir John Murray. Physical oceanography is written by Dr. Helland-Hansen, the phytoplankton by Professor Gran, the bottom fauna by Professor Appellöf, and the narrative, equipment, fishes of the sea bottom, pelagic animals and general biology are by Dr. Hjort, there being ten chapters in the book.

The signal success of this expedition was due to two factors: a corps of able, enthusiastic students already distinguished by high achievement in these studies, and the possession of exceptionally good apparatus provided through the generous support of the Norwegian government and of Sir John Murray.

Thus the ship carried a huge otter trawl, and a Petersen fish trawl, so efficient that in one haul they captured nearly as many individual fishes as the *Challenger* discovered in its twenty-five hauls between 1,500 and 2,000 fathoms. There were also large vertical closing nets 3 meters wide and 9 long, and hauls were at times made with ten nets and trawls out at various depths at one and the same time. The collections were thus exceptionally rich in species, some new and many rare forms such as *Spirula, Melanocetus krechi,* a remarkable genus allied to *Gastrostomus,* new Leptocephali, many larval fishes with telescopic eyes and a specimen of the giant squid.

But the results, important as they may be, will not be chiefly memorable for the new species and interesting forms discovered, for the intensive studies of the physics and chemistry of the sea,

and the application of new methods made possible by improved apparatus has led to the dicsovery of certain general laws.

For example, Professor Gran, using a steam centrifuge capable of centrifuging 1,200 c.c. of sea water at a speed of 700–800 revolutions per minute, discovered the unsuspected fact that the smallest pelagic plants, the nannoplankton which pass readily through the meshes of an ordinary silk net, are far more abundant than are the larger forms. He found, also, that pelagic plant life is most abundant at depths of 10–20 meters, but becomes extremely scanty below 100 meters, and he confirms the conclusion of Nathansohn that marine plant-life thrives best where ascending currents bring upward a supply of nitrogenous compounds derived from the decomposition of organic matter in the deep sea. Gran concludes that in the tropics the phytoplankton consists of numerous species, most of which are rare, whereas in the colder waters there are few species but great aggregations of individuals.

Professor Helland-Hansen made use of a new form of photographic-plate photometer which he himself had invented. He was thus enabled to demonstrate that a good deal of sunlight penetrates to a depth of 1,000 meters, but at 1,700 meters his plates were unaffected by an exposure of 2 hours' duration. The sun's rays at a depth of 500 meters in clear tropical water still retain a definite direction, not having yet become diffuse. But the most important discovery is the fact that the red rays are absorbed more quickly than the blue. Thus little or no red light can penetrate into the depths and the dark red color so characteristic of the animals of the deep sea is explained by the fact that, there being no red light where they live, they appear black and are thus rendered invisible.

The ship was well supplied with oceanographic apparatus, having a number of Ekman's current meters, Richter's reversing thermometers, Petterson-Nansen's water bottle and Petterson's insulating deep-sea bottle, enabling one to bring samples of water to the deck and there determine the temperature which the water had when at the bottom of the sea.

The *Michel Sars* is certainly to be congratulated upon the success attending their skillful use of this apparatus. For example, the vessel ventured to anchor in a depth of 400 meters over a hard bottom in the straits of Gibraltar and then to make use of two Ekman current meters, one at a constant depth of 10 meters and the other at various depths down to the bottom. They achieved the first accurate quantitative determinations of

the currents ever attained at Gibraltar and found that there is a surface current passing inward from the Atlantic to the Mediterranean, while at the same time a strong bottom-current of dense water passes outward into the Atlantic. The boundary between these two currents is usually at a depth of about 150 fathoms but this is greatly affected by the tidal conditions, for during one hour the current flowed outward toward the Atlantic even at the surface.

Other studies in the open Atlantic far from land enabled them to distinguish currents due to tidal action at the surprising depth of more than 1,000 fathoms. Indeed, a most interesting part of the book is devoted to the discussion of the physics of oceanic and tidal currents, and the expedition has achieved a hopeful purpose if it has done little more than point out the possibilities of research in the complex subject of the relation between tidal waves and tidal currents. The right-handed deviation of moving masses of water in the northern hemisphere due to the earth's rotation is clearly shown as a result of titration to determine the densities of sea water at various depths. Thus it is shown that the dense, relatively warm water of the Mediterranean spreads out in a great wedge in the intermediate depths of the Atlantic, and that most of this water moves northward off the coast of Portugal.

Through studies in density it is shown that the so-called "Gulf Stream" water overlies the cold water of Arctic origin.

But it is impossible to do more than merely indicate a few of the more important facts and laws presented in this remarkable book. In fact it is impossible to review a work which is itself a review of all previous studies as well as a medium for the presentation of newly discovered facts.

An appreciated feature of the book is the numerous charts, maps and hydrographic sections showing density and temperature gradients, the distribution of oxygen in the ocean, and the most recent results of exploration in soundings.

For example, it is shown that in 1910 the temperature at 400 fathoms in a certain place was 5° C. colder than in 1873 when the *Challenger* worked in the same region.

The area of the ocean is stated to be 139,295,000 square miles, of which 58.42 per cent. has a depth of between 2,000–3,000 fathoms, and about one sixth is less than 1,000 fathoms deep.

The hydrographic sections from the Sargasso Sea to Newfoundland, and from Newfoundland to Ireland, as well as the more intensive studies of the Spanish Bay and Gibraltar, and of

the Wyville Thomson Ridge between the Faroe and Shetland Islands are especially interesting.

Other charts based upon the researches of Knudsen, Ostenfeld, and Brenneke show the distribution of dissolved oxygen in the Atlantic down to 1,500 fathoms between 60° N. and 50° S. latitude, proving that the higher the salinity and the temperature the less the absorption of oxygen, and hence the relative deficiency of oxygen in the surface waters of the tropics.

In a work of this magnitude there must needs be errors and omissions, but these are so infrequent and of such small moment that it seems ungracious to call attention to a few of the more noticeable. The impalpable chalky deposit found in coral reef regions is still referred to as "coral mud," although in 1910 Vaughan stated that it was a chemical precipitate, and this enabled G. Harold Drew, of Cambridge, to demonstrate that it is actually a precipitate caused by the action of a bacillus in depriving the warm tropical water of its nitrogen, thus enabling the calcium to combine with the dissolved CO_2 to form calcium carbonate.

In the table at the bottom of page 175, the statement "the number of grams of salts per *liter* of sea water" should read "the number of grams of salts per *1,000 grams* of sea water."

On page 187 "*purifying* sarcodic matter" should read "*putrifying* sarcodic matter." But such criticisms are really puerile, and are given chiefly to show the negligible character of the errors in the book, the editorial work upon which reflects great credit upon Messrs. James Chumley and Dr. Caspari.

A happy feature in the editorial arrangement of the book is the system of marginal notes which enable one quickly to discover the subjects of each paragraph. One regrets the absence of a bibliography, but the introduction of such a list would have perhaps too greatly enlarged the size of the book.

Apart from the purely scientific side which we have been considering the book indicates the possible practical value of these studies. For example, it is shown that the growth-rate of pine trees on the coast of Norway bears a direct relation to the temperature of the ocean water, and for six successive years when the amount of heat in the "Gulf Stream water" was great in the month of May the air temperature in Norway was high in the following winter. The water-temperature also bears a direct relation to the time of the blossoming of *Tussilago farfara* at Upsala. Also, Dr. Hjort shows that the southern limit of the

valuable boreal food fishes everywhere coincides with the isotherm of 10° C. at a depth of 100 meters.

ALFRED G. MAYER.

THE GROWTH OF GROUPS IN THE ANIMAL KINGDOM

ANY one who makes an intensive study of many representatives of some organism becomes impressed by the fact that they form many slightly differing groups, and is led to ask how these diversities have arisen. This has been the experience of Lloyd[1] in studying the rats of India, in connection with the problem of plague prevention. He has therefore been moved to present in book form his impressions as to how the observed groups probably arise, together with the facts on which these impressions are based; and some general deductions from these impressions.

The facts observed in the study of the rats are of the following character: (1) Small groups of rats differing in some respects from the forms regarded as typical, occur frequently here and there. (2) Such groups, with the same exceptional characters, appear in various widely separated places, showing that the different small groups have arisen independently of each other. (3) "This is true, however, only in the case of groups whose peculiarity appears as a single character unit. Those groups whose peculiarity is made up of several uncorrelated characters arise on one occasion only" (p. 50). Descriptions and figures of many such cases are given; the account here is of much value and interest.

Such facts naturally lead the author to hold that groups of this sort have arisen by mutation: that is, by a dropping out or alteration of single unit characters, in the Mendelian sense; that the same character often drops out in different localities, giving rise to small groups of independent origin, yet having the same distinctive features. This part of the discussion would have been given more precision by consideration of the work on inheritance in rodents and other organisms, as carried on by Castle and others. Further, the pure line work with homozygotes and in vegetative reproduction might give definiteness to many of the author's rather vague views as to the nature of these groups. The conclusions of Lloyd along these lines will appear somewhat halting and loose to persons steeped in the experimental work in

[1] "The Growth of Groups in the Animal Kingdom," by R. E. Lloyd, Longmans, Green and Co., 1912, 185 pp., $1.75.

the two fields mentioned. Lloyd's distinctive contribution is the demonstration that there exist in certain wild organisms the same conditions that are found in experimentation.

The author's interest lies mainly in bringing the work into relation with the species concept as employed in systematic zoology, and in showing its opposition to what he calls the "accepted" view that diverse groups of organisms arise gradually, by a process of selection among minute gradations. He shows that many of the so-called species of rats are distinguished from each other in the same way as are the small groups he has observed; therefore there is not ground for supposing all the members of such species to be descended from a common stock. "Animal species appear to be conventional rather than real" (p. 117). But among the author's fluctuating views on this point is the doubtful assertion that "there seems to be reason for believing that the distinction between specific and varietal characters which was recognized by De Vries in plants is also recognizable among higher animals" (p. 139); which would seem to imply that there is some sort of reality underlying the distinction of species. The matter is not analyzed with precision.

In a special chapter the author attempts to apply to certain problems of disease and abnormality in man the idea that new forms arise by mutation. Here again, those who have at hand such a work as Davenport's "Eugenics" will find the presentation vague, though tending in the same direction as in the work mentioned.

In a concluding chapter the author abandons empirical evidence for an attempt to criticize the theory of natural selection from a general and philosophical point of view. Much is made of the supposed requirement that variation should be "in all directions," the criticism depending "on the assumption that we can not imagine things varying in all directions" (p. 175). Further, adaptation is held not to be a phenomenon needing explanation. The rest of the discussion is of a similar character, showing less precision of analysis than any other part of the work.

The author states in the preface that the book is offered "as an assortment of opinions which may be of suggestive value." The observed facts in regard to the diverse groups of rats, however, make it more than this.

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